

YELLOWFIN SOLE

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Executive Summary

The following changes have been made to this assessment relative to the November 2002 SAFE:

Changes to the input data

- 1) 2002 fishery age composition.
- 2) 2002 survey age composition.
- 3) 2003 trawl survey biomass point estimate and standard error.
- 4) Estimate of the discarded and retained portions of the 2002 catch.
- 5) Estimate of total catch through 27 September 2003.

Assessment results

- 1) The projected age 2+ biomass for 2004 is 1,557,200 t.
- 2) The projected female spawning biomass for 2004 is 446,400 t.
- 3) The recommended 2004 ABC is 113,500 t based on an $F_{40\%}$ (0.115) harvest level.
- 4) The 2004 overfishing level is 134,700 t based on an $F_{35\%}$ (0.138) harvest level.

	2002 Assessment Recommendations for 2003 harvest	2003 Assessment Recommendations For 2004 harvest
Total biomass	1,554,190 t	1,557,200 t
ABC	113,600 t	113,500 t
Overfishing yield	134,800 t	134,700 t
F_{ABC}	$F_{0.40} = 0.115$	$F_{0.40} = 0.115$
$F_{\text{overfishing}}$	$F_{0.35} = 0.138$	$F_{0.35} = 0.138$

New in this assessment

A Ricker spawner recruit curve is fit inside the stock assessment model to estimate recruitment. MSY is then calculated from two different spawner-recruit time-series data sets and compared. Based on these results, considerations for moving from tier 3 to tier 1 are discussed.

Introduction

The yellowfin sole (*Limanda aspera*) is one of the most abundant flatfish species in the eastern Bering Sea (EBS) and is the target of the largest flatfish fishery in the United States. They inhabit the EBS shelf and are considered one stock. Abundance in the Aleutian Islands region is negligible.

Yellowfin sole are distributed in North American waters from off British Columbia, Canada, (approx. lat. 49° N) to the Chukchi Sea (about lat. 70° N) and south along the Asian coast to about lat. 35° N off the South Korean coast in the Sea of Japan. Adults exhibit a benthic lifestyle and occupy separate winter, spawning and summertime feeding distributions on the eastern Bering Sea shelf. From over-winter grounds near the shelf margins, adults begin a migration onto the inner shelf in April or early May each year for spawning and feeding. The directed fishery typically occurs from spring through December.

Catch History

Yellowfin sole have annually been caught with bottom trawls on the Bering Sea shelf since the fishery began in 1954. The catch locations of vessels targeting on yellowfin sole in 2001, by quarter, are shown in the Appendix figures. The total catch (t) since implementation of the MFCMA in 1977 are shown in Table 4.1.

Yellowfin sole were overexploited by foreign fisheries in 1959-62 when catches averaged 404,000 t annually (Fig. 4.1). As a result of reduced stock abundance, catches declined to an annual average of 117,800 t from 1963-71 and further declined to an annual average of 50,700 t from 1972-77. The lower yield in this latter period was partially due to the discontinuation of the U.S.S.R. fishery. In the early 1980s, after the stock condition had improved, catches again increased reaching a recent peak of over 227,000 t in 1985.

During the 1980s, there was also a major transition in the characteristics of the fishery. Yellowfin sole were traditionally taken exclusively by foreign fisheries and these fisheries continued to dominate through 1984. However, U.S. fisheries developed rapidly during the 1980s in the form of joint ventures, and during the last half of the decade began to dominate and then take all of the catch as the foreign fisheries were phased out of the EBS. Since 1990, only domestic harvesting and processing has occurred.

The 1997 catch of 181,389 t was the largest since the fishery became completely domestic which decreased to 101,201 t in 1998. The 2002 catch totaled 73,000 t and 74,300 t have been caught in 2003 through 27 September. Thus far, the 2003 catch is 65% of the ABC and 89% of the TAC. The yellowfin sole harvest in 2003 has been constrained by two seasonal closures due to the attainment of halibut PSC limits: from April 16-May 12 and from June 6-June 29. In addition, zone 1 was closed on May 22 for the remainder of 2003 to prevent exceeding the 2003 bycatch allowance of red king crab specified for the yellowfin sole target fishery.

The catch information presented above also includes yellowfin sole which were discarded in DAP fisheries since their beginning in 1987. Discard estimates are calculated from weekly observer discard estimates, by target fishery, applied to the weekly 'blend' estimate of retained catch from the NMFS regional office summed over the fishing year.

<u>Year</u>	<u>Retained</u>	<u>Discards</u>
1987	3	1
1988	7,559	2,274
1989	1,279	385
1990	10,093	4,200
1991	89,054	26,788
1992	103,989	45,580
1993	76,798	26,838
1994	107,629	36,948

1995	96,718	28,022
1996	101,324	28,334
1997	149,570	31,818
1998	80,365	20,836
1999	55,202	12,118
2000	69,788	14,062
2001	54,759	8,635
2002	62,050	10,950

The rate of discard has ranged from a low of 14% of the total catch in 2001 to 30% in 1992. The trend has been toward fuller retention of the catch in recent years. Discarding primarily occurs in the yellowfin sole directed fishery, with lesser amounts in the Pacific cod, rock sole, flathead sole, and 'other flatfish' fisheries (Table 4.2).

Data

The data used in this assessment include estimates of total catch, bottom trawl survey biomass estimates and their attendant 95% confidence intervals, catch-at-age from the fishery and population age composition estimates from the bottom trawl survey. Weight-at-age and proportion mature-at-age are also available from studies conducted during the bottom trawl surveys.

Fishery Catch and Catch-at-Age

This assessment uses fishery catch data from 1955- September 27 2003 (Table 4.1) and fishery catch-at-age (numbers) from 1964-2002 (Table 4.3, 1977-2002).

Survey Biomass Estimates and Population Age Composition Estimates

The survey estimates of population numbers-at-age from 1975 and 1979-2002 are used in the assessment model and are shown for 1982-2002 in Table 4.4. Biomass (t) estimates from AFSC surveys conducted in a standardized area of the EBS encompassing waters from 20 to 200 m and from the Alaska Peninsula north to a latitude of St. Matthew and Nunivak Islands are given below:

Year	Age Groups		Total	95% confidence Interval of Total	
	0-6	7 plus			
1975	169,500	803,000	972,500	812,300	- 1,132,700
1979	211,500	1,655,000	1,866,500	1,586,000	- 2,147,100
1980	235,900	1,606,500	1,842,400	1,553,200	- 2,131,700
1981	343,200	2,051,500	2,394,700	2,072,900	- 2,716,500
1982	685,700	2,692,100	3,377,800	2,571,000	- 4,184,600
1983	198,000	3,337,300	3,535,300	2,958,100	- 4,112,400
1984	172,800	2,968,400	3,141,200	2,636,800	- 3,645,600
1985	166,200	2,277,500	2,443,700	1,563,400	- 3,324,000
1986	80,200	1,829,700	1,909,900	1,480,700	- 2,339,000
1987	125,500	2,487,600	2,613,100	2,051,800	- 3,174,400
1988	45,600	2,356,800	2,402,400	1,808,400	- 2,996,300
1989	196,900	2,119,400	2,316,300	1,836,700	- 2,795,800
1990	69,600	2,114,200	2,183,800	1,886,200	- 2,479,400
1991	60,000	2,333,300	2,393,300	2,116,000	- 2,670,700
1992	145,900	2,027,000	2,172,900	*	
1993	188,200	2,277,200	2,465,400	2,151,500	- 2,779,300
1994	142,000	2,468,500	2,610,500	2,266,800	- 2,954,100
1995	213,000	1,796,700	2,009,700	1,724,800	- 2,294,600
1996	161,600	2,137,000	2,298,600	1,749,900	- 2,847,300
1997	239,330	1,924,070	2,163,400	1,907,900	- 2,418,900
1998	150,756	2,178,844	2,329,600	2,033,130	- 2,626,070
1999	57,700	1,246,770	1,306,470	1,118,800	- 1,494,150
2000	73,200	1,508,700	1,581,900	1,382,000	- 1,781,800
2001	135,300	1,719,900	1,855,200	1,600,300	- 2,110,000
2002	82,700	1,920,700	2,003,400	1,728,200	- 2,278,600
2003			2,284,800	1,847,500	- 2,722,200

* 95% confidence intervals cannot be calculated for 1992 since the total estimate includes an unsampled area for which a 3 year average was used as a proxy.

Estimates are given separately for unexploited ages (less than age 7) and exploited ages (ages 7 and older) except for 2003 where age data are not yet available. The data show a doubling of biomass between 1975 and 1979 with a further increase to over 2.3 million t in 1981 for the exploitable portion of the population. Survey abundance estimates fluctuated erratically from 1981 to 1990 with biomass ranging from as high as 3.5 million t in 1983 to as low as 1.9 million t in 1986. Biomass estimates since 1990 indicate an even trend at high levels of abundance for yellowfin sole, with the exception of the results from the 1999 and 2000 summer surveys, which were at lower levels.

Indices of relative abundance available from AFSC surveys have also shown a major increase in the abundance of yellowfin sole during the late 1970s increasing from 21 kg/ha in 1975 to 51 kg/ha in 1981 (Fig. 4.2, Bakkala and Wilderbuer 1990). These increases have also been documented through Japanese commercial pair trawl data and catch-at-age modeling in past assessments (Bakkala and Wilderbuer 1990).

Since 1981, the survey CPUEs have fluctuated widely. For example, they increased from 51 kg/ha in 1981 to 84 kg/ha in 1983 and then declined sharply to 49 kg/ha in 1985. They continued to fluctuate from 1986-

90, although with less amplitude (Fig 4.2). From 1990-1998, the estimated CPUE was relatively stable but have declined the past two years. Fluctuations of the magnitude shown between 1980 and 1990 and again between 1998 and 1999 are unreasonable considering the combined elements of slow growth and long life span of yellowfin sole and low exploitation rate, characteristics which should produce more gradual changes in abundance.

Variability of yellowfin sole survey abundance estimates (Fig. 4.3) is in part due to the availability of yellowfin sole to the survey area (Nichol, 1998). Yellowfin sole are known to undergo annual migrations from wintering areas off the shelf-slope break to nearshore waters where they spawn throughout the spring and summer months (Nichol, 1995; Wakabayashi, 1989; Wilderbuer et al., 1992). Exploratory survey sampling in coastal waters of the eastern Bering Sea indicate that yellowfin sole concentrations can be greater in these shallower areas not covered by the standard AFSC survey. Commercial bottom trawlers have commonly found high concentrations of yellowfin sole in areas such as near Togiak Bay (Low and Narita, 1990) and in more recent years from Kuskokwim Bay to just south of Nunivak Island. The coastline areas are sufficiently large enough to offer a substantial refuge for yellowfin sole from the current survey.

Over the past 15 years survey biomass estimates for yellowfin sole have shown a positive correlation with shelf bottom temperatures (Nichol, 1998); estimates have been low during cold years. The 1999 survey, which was conducted in exceptionally cold waters, indicated a biomass estimate that was unrealistically low.

The bottom temperatures during the 2000 survey were much warmer than in 1999, and the biomass increased, but still did not approach estimates from earlier years. Average bottom temperature and biomass both increased again in 2001 – 2003, with the 2003 value the highest observed over the 22 year time series. Given that both 1999 and 2000 surveys were conducted two weeks earlier than previous surveys, it is possible that the time difference may also have affected the availability of yellowfin sole to the survey. If, for example, the timing of peak yellowfin sole spawning in nearshore waters corresponded to the time of the survey, a greater proportion of the population would be unavailable to the standard survey area.

We propose two possible reasons why survey biomass estimates are lower during years when bottom temperatures are low. First, catchability may be lower because yellowfin sole may be less active when temperatures are low. Less active fish may be less susceptible to herding, and escapement under the footrope of survey gear may increase if fish are less active. Secondly, bottom temperatures may influence the timing of the inshore spawning migrations of yellowfin sole and therefore affect their availability to the survey area.

Because yellowfin sole spawning grounds include nearshore areas outside the survey area, availability of fish within the survey area can vary with the timing of this migration and the timing of the survey. As was the case in 2000, greater than average catches along the survey border outside of Kuskowkim bay may indicate that a significant portion of the biomass lies outside this border (Fig 4.4).

Length and Weight-at-Age and Maturity-at-Age

Mean lengths and weights at age of yellowfin sole based on 12 years (1979-90) of data from AFSC surveys and the length (cm) – weight (g) relationship ($W = 0.0097217 * L^{**} 3.0564$) are as follows:

Age	cm	in	g	lb
3	11.1	4.4	15.31	0.03
6	19.9	7.8	90.97	0.2
7	22.1	8.7	124.8	0.27
8	24	9.4	160.07	0.35
9	25.6	10.1	195.44	0.43
10	27	10.6	229.92	0.51
11	28.2	11.1	262.79	0.58
12	29.2	11.5	293.59	0.65
13	30.1	11.9	322.06	0.71
14	30.9	12.2	348.09	0.77
15	31.6	12.4	371.67	0.82
16	32.1	12.6	392.87	0.87
17	32.6	12.8	411.81	0.91
18	33.1	13	428.65	0.94
19	33.5	13.2	443.55	0.98
20	33.8	13.3	456.69	1.01
21	34	13.4	468.25	1.03
22	34.3	13.5	478.38	1.05
23	34.5	13.6	487.24	1.07
24	34.7	13.7	494.99	1.09
25	34.8	13.7	501.74	1.11
26	34.9	13.7	507.61	1.12

Changes in length and weight at age over time has been documented for Bering Sea rock sole (Walters and Wilderbuer 2000) and Bering Sea and Gulf of Alaska Pacific halibut (Clark et al 1999). We examined our assumption of time invariant growth in length and weight of yellowfin sole by comparing the weight and length at age from fish collected during the 1987, 1994, 1999, 2000 and 2001 surveys (Fig. 4.5). Over the age range of 4 to 14 years (fish ageing > 14 years has more error and smaller sample sizes) there are only small differences in length and weight at age from 1987 to 2001. Largest annual differences in weight at age were found in 1999 (a cold year) which were not present in the same cohorts in 2001 (a warmer year). These differences seem to be more related to annual metabolic rate than a shift in population-wide growth. Based on these findings, we concluded that use of a single weight at age vector was justified for this assessment.

Maturity information collected from yellowfin sole females during the 1992 and 1993 eastern Bering Sea trawl surveys is used in this assessment (Table 4.5). Nichol (1994) estimated the age of 50% maturity at 10.5 years based on the histological examination of 639 ovaries. In the case of most north Pacific flatfish species, including yellowfin sole, sexual maturity occurs well after the age of entry into the fishery. Yellowfin sole are 90% selected to the fishery by age 11 but females have been found to be only 50% mature at this age.

Parameters of the von Bertalanffy growth curve for yellowfin sole from 12 years of combined data have been estimated as follows:

age range	Linf(cm)	K	t0
3-26	35.8	0.147	0.47

Analytic Approach

Model Structure

The abundance, mortality, recruitment and selectivity of yellowfin sole were assessed with a stock assessment model using the AD Model builder language (Ianelli and Fournier 1998). The conceptual model is similar to that implemented in the stock synthesis program (Methot 1990, Fournier and Archibald 1982). The model is a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliary information. The assessment model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics is optimized by maximizing a log(likelihood) function.

The suite of parameters estimated by the model are classified by three likelihood components:

Data component	Distributional assumption
Trawl fishery catch-at-age	Multinomial
Trawl survey population age composition	Multinomial
Trawl survey biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (Table 4.6). The likelihood components may be weighted by an emphasis factor, however, equal emphasis was placed on fitting each likelihood component in the yellowfin sole assessment except for the catch. The AD Model Builder software fits the data components using automatic differentiation (Griewank and Corliss 1991) software developed as a set of libraries (AUTODIFF C++ library). Table 4.6 presents the key equations used to model the yellowfin sole population dynamics in the Bering Sea and Table 4.7 provides a description of the variables used in Table 4.6.

Sharp increases in trawl survey abundance estimates for most species of Bering Sea flatfish between 1981 and 1982 indicate that the 83-112 trawl was more efficient for capturing these species than the 400-mesh eastern trawl used in 1975, and 1979-81. Allowing the model to tune to these early survey estimates would most likely underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. Although this underestimate would have little effect on the estimate of current yellowfin sole biomass, it would affect the spawner and recruitment estimates for the time-series. Hence, the pre-1982 survey biomass estimates were omitted from the analysis.

The model of yellowfin sole population dynamics was evaluated with respect to the observations of the time-series of survey and fishery age compositions and the survey biomass trend since 1982.

Parameters Estimated Independently

Natural mortality (M) was initially estimated by a least squares analysis. Catch-at-age data were fitted to Japanese pair trawl effort data while varying the catchability coefficient (q) and M simultaneously. The best fit to the data (the point where the residual variance was minimized) produced a M value of 0.12 (Bakkala and Wespestad 1984). This was also the value which provided the best fit to the observable population characteristics when M was profiled over a range of values in the stock assessment model (Wilderbuer 1992). Thus, a natural mortality value of 0.12 is used in this assessment.

Yellowfin sole maturity schedules were estimated from in situ observations as discussed in a previous section (Table 4.5).

Parameters Estimated Conditionally

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Survey catchability	Year class strength	Spawner-recruit	Total
50	4	2	69	2	127

The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery data, the entry of another year class into the observed population and fitting a spawner-recruit model.

Year class strengths

The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate for each cohort as it moves through the population over time using the population dynamics equations given in Table 4.6.

Selectivity

Fishery and survey selectivity was modeled in this assessment using the two parameter formulation of the logistic function, as shown in Table 4.6. The model was run with an asymptotic selectivity curve for the older fish in the fishery and survey, but still was allowed to estimate the shape of the logistic curve for young fish. The oldest year classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the age category 20+ years.

Fishing Mortality

The fishing mortality rates (F) for each age and year are calculated to approximate the catch weight by solving for F while still allowing for observation error in catch measurement. A large emphasis was placed on the catch likelihood component.

Survey Catchability

A past assessment (Wilderbuer and Nichol 2001) first examined the relationship between estimates of survey biomass and bottom water temperature. To better understand how water temperature may affect the catchability of yellowfin sole to the survey trawl, catchability was estimated for each year in the stock assessment model as:

$$q = \alpha + \beta T$$

where q is catchability, T is the average annual bottom water temperature at survey stations less than 100 m, and $-\alpha$ and β are parameters estimated by the model. The result of the linear fit to bottom temperature vs. estimated q is shown in Figure 4.6.

Spawner-Recruit Estimation

Annual recruitment estimates were constrained to fit a Ricker (1958) form of the stock recruitment relationship as follows:

$$R = \alpha S e^{-\beta S}$$

where R is age 1 recruitment, S is female spawning biomass (t) the previous year, and α and β are parameters estimated by the model. The spawner-recruit fitting is estimated in a later phase after initial estimates of survival, numbers-at-age and selectivity are obtained.

Model Evaluation

Three models were evaluated in last year's assessment: 1) survey catchability = 1.0; 2) a single value of survey catchability was estimated for the entire time series; and 3) survey catchability modeled as a linear function of average bottom water temperature at stations less than or equal to 100 m depth. The likelihood profile of q from the 3rd model indicated a small variance with a narrow range of likely values. The probability of q being as low or lower than the value of 1.0 assumed in the first model, given the data, appears to be very low. In addition, supporting evidence from experiments examining the bridle efficiency of the Bering Sea survey trawl indicate that yellowfin sole are herded into the trawl path from an area between the wing tips of the net and the point where the bridles contact the seafloor (Somerton and Munro 2001) indicating that the survey trawl catchability is greater than 1.0. Thus the model of choice for this assessment, as last year, is the model which estimates an annual q by considering average bottom water temperature because it provides a significantly better fit to the data overall, and because the value of 1.0 for q no longer appears realistic. The approach was accepted by the SSC in the 2001 stock assessment.

Model Results

Fishing Mortality and Selectivity

The assessment model estimates of the annual fishing mortality on fully selected ages are given in Table 4.8. The large 1997 catch corresponds to a full-selection F value of 0.15, which is higher than the 1977-2002 average full selection- F of 0.11 but only represents an exploitation fraction of 6%. Selectivities estimated by the model (Table 4.9, Figure 4.7) indicate that yellowfin sole are 50% selected by the fishery at age 9 and nearly fully selected by age 13.

Abundance Trend

The model estimates q at an average value of 1.35 for the period 1982-2003 which results in the model estimate of the 2003 total biomass at 1,571,580 t (Table 4.10). Model results indicate that yellowfin sole total biomass (age 2+) was at low levels during most of the 1960s and early 1970s (600,000-800,000 t) after a period of high exploitation (Table 4.10, Figure 4.7, bottom left panel). Sustained above average recruitment from 1967-76 combined with light exploitation resulted in a biomass increase to a peak of 2.5 million t by 1985. The population biomass has since been in a slow decline as the strong 1981 and 1983 year-classes have passed through the population with only the 1991 year class at levels observed during the 1970s. Over the past fifteen years stock biomass has declined nearly 1 million t since the peak biomass observed in 1985.

The female spawning biomass has also steadily declined since the peak in 1985, with a 2003 estimate of 490,000 t (28% decline). This level of spawning biomass is consistent with the estimates since 1999 and is about 125% of the $B_{40\%}$ level (Fig. 4.8). The model estimate of yellowfin sole population numbers at age for all years is shown in Table 4.11 and the resulting fit to all the observed fishery and survey age compositions input into the model are shown in the Appendix. The fit to the trawl survey biomass estimates are shown in Figure 4.7. Allowing q to be correlated with annual bottom temperature provides a close fit to the bottom trawl survey estimates.

Both the trawl survey and the stock assessment model indicate that the yellowfin sole resource slowly increased during the 1970s and early 1980s to a peak level during the mid-1980s and that the resource has been in a slow, consistent decline since then (Figure 4.7). Above average recruitment from the 1991 year-class is expected to maintain the abundance of yellowfin sole at a level above B_{40} in the near future. The stock assessment projection model (later section) indicates a continued slow decline in female spawning biomass in the near future if the fishing mortality rate continues at the same level as the average of the past 5 years.

Total Biomass

The stock assessment model estimate of total biomass (begin year population numbers multiplied by mid-year weight at age) is used to recommend the ABC for 2004. Including the 2003 reported catch through 27 September (including discards), the model projects the total biomass for 2004 at **1,557,200 t**.

Recruitment Trends

The primary reason for the sustained increase in abundance of yellowfin sole during the 1970s and early 1980s was the recruitment of a series of stronger than average year classes spawned in 1967-76 (Figure 4.9 and Table 4.12). The 1981 year class was the strongest observed (and estimated) during the 46 year period analyzed and the 1983 year class was also very strong. Survey age composition estimates and the assessment model also estimate that the 1987 and 1988 year classes were average and the 1991 year class was strong. With the exception of these three year classes, recruitment over the past 13 years has been below the 48 year average which has caused the population decline. The 1995 year-class, which was strong in the 2002 survey age composition, could also be of above average strength.

Tier 1 Considerations

The SSC has requested that flatfish assessments which have a lengthy time-series of stock and recruitment estimates explore management under a Tier 1 harvest policy. In the case of yellowfin sole, we have a lengthy time series of 45 years. MSY is an equilibrium concept and its value is dependent on both the spawner-recruit data which we assume represents the equilibrium stock size-recruitment relationship and the model used to fit the data. In the stock assessment model used here, a Ricker form of the stock-recruit relationship was fit to these data and estimates of F_{MSY} and B_{MSY} were calculated, assuming that the fit to the stock-recruitment data points represent the long-term productivity of the stock. However, very different estimates of F_{MSY} and B_{MSY} were obtained, depending on which years of stock-recruitment data points were included in the fitting procedure (Fig. 4.10). When we fit the entire time-series from 1954-1999, we include large recruitments that occurred at a low spawning stock size in the 1960s and early 1970s which indicate a productive stock that is able to replace itself quite well at low stock sizes. Therefore, MSY and F_{MSY} are relatively high values (217,000 t and 0.37, respectively) and B_{MSY} is 208,800 t. If we limit the data to consider only recruitments which occurred after the well-documented regime shift in 1977, much lower values of MSY and F_{MSY} are obtained (150,100 t and 0.22, respectively) and B_{MSY} is 249,800 t.

This calls into concern whether a single fit of stock recruitment time-series data is able to reliably capture the long-term reproductive potential of the yellowfin sole stock. A recent analysis of flatfish recruitment indicates that temporal trends in winter spawning flatfish production in the Eastern Bering Sea are consistent with the hypothesis that decadal scale climate variability influences marine survival during the early life history period (Wilderbuer et al. 2002). Periods of cross-shelf advection of flatfish larvae was found to coincide with synchronous above-average recruitment (1980s) whereas periods of weak advection or advection to the west were associated with poor recruitment (1990s). These changes in stock productivity were found to coincide with a decadal scale shift in atmospheric forcing which warrant caution when trying to determine the long-term reproductive potential of this stock.

The aforementioned analysis was performed for rock sole, arrowtooth flounder and flathead sole, species which spawn in the winter in offshore areas and are seemingly reliant upon advection to nursery areas 3-4 months later. In contrast, yellowfin sole are known to spawn in shallow near shore areas of northern Bristol Bay, primarily in May and June, where it would seem that advection would play a diminished role in juvenile survival resulting in less variable recruitment. However, it is evident from Figure 4.9 that the time series of year class strength for yellowfin sole has shifts in production (1956-66, 1967-77, 1984-97). These shifts may be a cause of concern if we assume that the long term productivity is closely related to spawning stock size while ignoring mechanisms governing the variability in production which may correspond to decadal (or longer) shifts in environmental conditions.

Given these concerns, the authors plan to perform a simulation study to determine the appropriateness of applying a harvest strategy from fitting the full time series for a fish stock experiencing temporal changes in reproductive potential due to changing oceanic conditions. For this assessment then, we recommend a continued Tier 3 harvest strategy.

Historical Exploitation Rates

Based on results from the stock assessment model, annual exploitation rates of yellowfin sole ranged from 3 to 10% of the total biomass since 1977, and have averaged 6% (Table 4.8).

Acceptable Biological Catch

After increasing during the 1970s and early 1980s, estimates from the stock assessment model indicate the total biomass has been at a slow decline from high levels of stock biomass since the peak in 1985. The estimate of total biomass for 2004 is 1,557,200 t.

The reference fishing mortality rate for yellowfin sole is determined by the amount of population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Equilibrium female spawning biomass is calculated by applying the female spawning biomass per recruit resulting from a constant $F_{0.40}$ harvest to an estimate of average equilibrium recruitment. The Alaska Fisheries Science Center policy is to use year classes spawned in 1977 or later to calculate the average equilibrium recruitment if no compelling reason exists to do otherwise. For this assessment we use the time-series of recruitment numbers estimated for 1978-2002 from the stock assessment model to estimate $B_{0.40} = 390,400$ t. The stock assessment projection model estimates the 2004 level of female spawning biomass at 446,400 t (B). Since reliable estimates of B, $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B > B_{0.40}$ ($446,400 > 390,400$, Figure 4.8), yellowfin sole reference fishing mortality is defined in tier 3a. For the 2004 harvest: $F_{ABC} \leq F_{0.40} = 0.115$ (full selection F values).

Acceptable biological catch is estimated for 2004 by applying the $F_{0.40}$ fishing mortality rate and age-specific fishery selectivities to the projected 2004 estimate of age-specific total biomass as follows:

$$ABC = \sum_{a=a_r}^{a_{nages}} \bar{w}_a n_a (1 - e^{-M-Fs_a}) \frac{Fs_a}{M + Fs_a}$$

where S_a is the selectivity at age, M in natural mortality, W_a is the mean weight at age, a_r is the age at recruitment to the fishery and n_a is the beginning of the year numbers at age. **This calculation results in a 2004 ABC of 113,500 t.**

Overfishing

The stock assessment analysis must also consider harvest limits, usually described as “overfishing” fishing mortality levels with corresponding yield amounts. Amendment 56 to the BSAI FMP now sets the harvest limit at the $F_{0.35}$ fishing mortality value or the fishing mortality rate which would reduce the spawning biomass per recruit to 35% of its unfished level (for tier 3a). The overfishing fishing mortality value, ABC fishing mortality value and their corresponding yields are given as follows:

Harvest level	F value	2004 Yield
FOFL = $F_{0.35}$	0.138	134,700 t
FABC = $F_{0.40}$	0.115	113,500 t

Biomass Projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2003 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2004 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2003. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2004, are as follow (“ $max F_{ABC}$ ” refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to $max F_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of $\max F_{ABC}$, where this fraction is equal to the ratio of the F_{ABC} value for 2004 recommended in the assessment to the $\max F_{ABC}$ for 2004. (Rationale: When F_{ABC} is set at a value below $\max F_{ABC}$, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of $\max F_{ABC}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1998-2002 average F . (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC} .)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL} . (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above $\frac{1}{2}$ of its MSY level in 2004 and above its MSY level in 2014 under this scenario, then the stock is not overfished.)

Scenario 7: In 2004 and 2005, F is set equal to $\max F_{ABC}$, and in all subsequent years, F is set equal to F_{OFL} . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2016 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 4.13 and Figure 4.11 indicate that yellowfin are not currently overfished and are not approaching an overfished condition.

Ecosystem Considerations

Ecosystem Effects on the stock

1) Prey availability/abundance trends

Yellowfin sole diet by life stage varies as follows: Larvae consume plankton and algae, early juveniles consume zooplankton, late juvenile stage and adults prey includes bivalves, polychaetes, amphipods, mollusks, euphausiids, shrimps, brittle stars, sculpins and miscellaneous crustaceans. Information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not been re-sampled since. The large populations of flatfish which have occupied the middle shelf of the Bering Sea over the past twenty years for summertime feeding do not appear food-limited. These populations have fluctuated due to the variability in recruitment success which suggests that the primary infaunal food source has been at an adequate level to sustain the rock sole resource.

2) Predator population trends

As juveniles, it is well-documented from studies in other parts of the world that flatfish are prey for shrimp species in near shore areas. This has not been reported for Bering Sea yellowfin sole due to a lack of juvenile

sampling and collections in near shore areas, but is thought to occur. As late juveniles they have been found in stomachs of Pacific cod and Pacific halibut; mostly on small yellowfin sole ranging from 7 to 25 cm standard length..

Past, present and projected future population trends of these predator species can be found in their respective SAFE chapters in this volume and also from Annual reports compiled by the International Pacific Halibut Commission. Encounters between yellowfin sole and their predators may be limited since their distributions do not completely overlap in space and time.

3) Changes in habitat quality

Changes in the physical environment which may affect yellowfin sole distribution patterns, recruitment success, migration timing and patterns and are catalogued in the Ecosystem Considerations Appendix of this SAFE report. Habitat quality may be enhanced during years of favorable cross-shelf advection (juvenile survival) and warmer bottom water temperatures with reduced ice cover (higher metabolism with more active feeding).

Fishery Effects on the ecosystem

1) The yellowfin sole target fishery contribution to the total bycatch of other non-prohibited species is shown for 1991-2002 in Table 4.14. The yellowfin sole target fishery contribution to the total bycatch of prohibited species is shown for 2001 and 2002 in Table 14 of the Economic SAFE (Appendix C) and is summarized for 2002 as follows:

<u>Prohibited species</u>	<u>Yellowfin sole fishery % of total bycatch</u>
Halibut mortality	30.0
Herring	12.4
Red King crab	11.7
<u>C. bairdi</u>	20.8
Other Tanner crab	43.3
Salmon	< 1

2) Relative to the predator needs in space and time, the yellowfin sole target fishery is not very selective for fish between 7-25 cm and therefore has minimal overlap with removals from predation.

3) The target fishery is not perceived to have an effect on the amount of large size target fish in the population due to it's history of light exploitation (6%) over the past 26 years.

4) Yellowfin sole fishery discards are presented in the Catch History section.

5) It is unknown what effect the fishery has had on yellowfin sole maturity-at-age and fecundity.

6) Analysis of the benthic disturbance from the yellowfin sole fishery is available in the Preliminary draft of the Essential Fish Habitat environmental Impact Statement.

Ecosystem effects on yellowfin sole			
Indicator	Observation	Interpretation	Evaluation
<i>Prey availability or abundance trends</i>			
Benthic infauna	Stomach contents	Stable, data limited	Unknown
<i>Predator population trends</i>			
Fish (Pacific cod, halibut, skates)	Stable	Possible increases to rock sole mortality	
<i>Changes in habitat quality</i>			
Temperature regime	Cold years yellowfin sole catchability and herding may decrease, timing of migration may be prolonged	Likely to affect surveyed stock	No concern (dealt with in model)
Winter-spring environmental conditions	Affects pre-recruit survival	Probably a number of factors	Causes natural variability
Yellowfin sole effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
<i>Fishery contribution to bycatch</i>			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Low bycatch levels of (spp)	Bycatch levels small relative to HAPC biota	No concern
Marine mammals and birds	Very minor direct-take	Safe	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be safe	No concern
<i>Fishery concentration in space and time</i>	Low exploitation rate	Little detrimental effect	No concern
<i>Fishery effects on amount of large size target fish</i>	Low exploitation rate	Natural fluctuation	No concern
<i>Fishery contribution to discards and offal production</i>	Stable trend	Improving, but data limited	Possible concern
<i>Fishery effects on age-at-maturity and fecundity</i>	unknown	NA	Possible concern

References

- Bakkala, R. G. and V. Wespestad. 1984. Yellowfin sole. In R. G. Bakkala and L. resources of the eastern Bering Sea and Aleutian Islands region in 1983, p. 37-60. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-53.
- Bakkala, R. G., V. Wespestad, and L. Low. 1982. The yellowfin sole (*Limanda aspera*) resource of the eastern Bering Sea--its current and future potential for commercial fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-33, 43p.

- Bakkala, R. G., and T. K. Wilderbuer. 1990. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1990, p. 60-78. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.
- Clark, W. G., Hare, S. R., Parns, A. M., Sullivan, P. J., Trumble, R. J. 1999. Decadal changes in growth and recruitment of Pacific halibut (*Hipploglossus stenolepis*). Can. J. fish. Aquat. Sci. 56, 242-252.
- Fournier, D. A. and C.P. Archibald. 1982. A general theory for analyzing catch-at-age data. Can. J. Fish Aquat. Sci. 39:1195-1207.
- Greiwan, A. and G. F. Corliss (eds) 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan. 6-8, Breckenridge, CO. Soc. Indust. And Applied Mathematics, Philadelphia.
- Haflinger, K. 1981. A survey of benthic infaunal communities of the Southeastern Bering Sea shelf. In Hood and Calder (editors) The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. 2. P. 1091-1104. Office Mar. Pol. Assess., NOAA. Univ. Wash. Press, Seattle, Wa 98105.
- Ianelli, J. N. and D. A. Fournier. 1998. Alternative age-structured analyses of the NRC simulated stock assessment data. In Restrepo, V. R. [ed.] Analyses of simulated data sets in support of the NRC study on stock assessment methods. NOAA Tech. Memo. NMFS-F/SPO-30. 96 p.
- Low, L. and R.E. Narita. 1990. Condition of groundfish resources in the Bering Sea-Aleutian Islands region as assessed in 1988. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-178, 224 p.
- Methot, R. D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. INPFC Bull.50:259-277. Symposium on application of stock assessment techniques to Gadoids.
- Methot, R. D. 1998. Application of Stock Synthesis to NRC Text Data Sets. In Analysis of Simulated Data Sets in Support of the NRC Study on Stock Assessment Methods, V. R. Restrepo (editor), Chap. 6. NOAA Tech. Mem. NMFS-F/SPO-30. U.S. Dep.Commer. NOAA, Nat. Mar. Fish. Serv.
- Nichol, D. R. . 1995. Spawning and maturation of female yellowfin sole in the eastern Bering Sea. In Proceedings of the international flatfish symposium, October 1994, Anchorage, Alaska, p. 35-50. Univ. Alaska, Alaska Sea Grant Rep. 95-04.
- Nichol, D.R. 1998. Annual and between sex variability of yellowfin sole, *Pleuronectes asper*, spring-summer distributions in the eastern Bering Sea. Fish. Bull., U.S. 96: 547-561.
- Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Can., (119) 300 p.
- Somerton, D.. A. and P. Munro. 2001. Bridle efficiency of a survey trawl for flatfish. Fish. Bull. 99:641-652 (2001).
- Wakabayashi, K. 1989. Studies on the fishery biology of yellowfin sole in the eastern Bering Sea. [In Jpn., Engl. Summ.] Bull. Far Seas Fish. Res. Lab. 26:21-152.

- Wakabayashi, K., R. Bakkala, and L. Low. 1977. Status of the yellowfin sole resource in the eastern Bering Sea through 1976. Unpubl. manuscript, 45p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C 15700, Seattle, Wa 98115.
- Walters, G. E. and T. K. Wilderbuer. 2000. Decreasing length at age in a rapidly expanding population of northern rock sole in the eastern Bering Sea and its effect on management advice. *Journal of Sea Research* 44(2000)17-26.
- Wilderbuer, T. K. 1992. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1993, chapter 3. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.
- Wilderbuer, T. K. 1993. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1994, chapter 3. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.
- Wilderbuer, T.K., G.E. Walters, and R.G. Bakkala 1992. Yellowfin sole, *Pleuronectes asper*, of the eastern Bering Sea: biological characteristics, history of exploitation, and management. *Mar Fish. Rev.* 54(4):1-18.
- Wilderbuer, T. K., A. B. Hollowed, W. J. Ingraham, Jr., P. D. Spencer, M. E. Conners, N. A. Bond, and G. E. Walters. Flatfish recruitment response to decadal climate variability and ocean conditions in the eastern Bering Sea. *Progress Oceanography* 55 (2002) 235-247.

Table 4.1- Catch of yellowfin sole 1977-2003. Catch for 2003 is the total through September 27, 2003.

Year	Foreign	Domestic		Total
		JVP	DAP	
1977	58,373			58,373
1978	138,433			138,433
1979	99,019			99,019
1980	77,768	9,623		87,391
1981	81,255	16,046		97,301
1982	78,331	17,381		95,712
1983	85,874	22,511		108,385
1984	126,762	32,764		159,526
1985	100,706	126,401		227,107
1986	57,197	151,400		208,597
1987	1,811	179,613	4	181,428
1988		213,323	9,833	223,156
1989		151,501	1,664	153,165
1990		69,677	14,293	83,970
1991			115,842	115,842
1992			149,569	149,569
1993			106,101	106,101
1994			144,544	144,544
1995			124,740	124,740
1996			129,659	129,659
1997			181,389	181,389
1998			101,201	101,201
1999			67,320	67,320
2000			83,850	83,850
2001			63,395	63,395
2002			73,000	73,000
2003			74,300	74,300

Table 4.2—Discard and retained catch, by target fishery, for yellowfin sole in 2001 and 2002.

2001			
Target Fishery	Discard	Retained	Grand Total
Bottom pollock	106	328	435
Pacific cod	1,116	146	1,263
other flatfish	4	10	14
Flathead sole	483	2,507	2,990
Mid-water pollock	112	46	158
Rock sole	842	3,098	3,940
Greenland turbot	3	2	5
arrowtooth flounder	1	10	12
Yellowfin sole	5,954	48,611	54,565
no retained groundfish	13	0	13
Total	8,635	54,759	63,395
2002			
Target Fishery	Discard	Retained	Grand Total
Atka mackerel	0.6	0	0.6
Pacific cod	1,583	429	2,012
Pollock	346	459	805
Rockfish	0	1	1
Arrowtooth flounder	0.4	18	18.4
Flathead sole	395	1,682	2,077
Rock sole	1,333	6,138	7,471
Yellowfin sole	7,386	53,192	60,578
Other flatfish	1	36	37
Other species	0		0
Total	11,044	61,955	73,000

Table 4.3—Yellowfin sole fishery catch-at-age numbers (millions), 1977-2002.

YEAR/AGE	7	8	9	10	11	12	13	14	15	16	17+
1977	18.7	42.5	35.7	70.5	48.3	15.8	4.7	2.9	2.2	0.6	0.3
1978	66.8	131.7	113.8	97.8	104.3	38.9	21.6	12.3	4.5	2.7	0.7
1979	20.7	49.4	89.6	82.9	61.3	45.1	22.9	7.1	4.1	1.5	1.3
1980	33.1	19.7	41.3	64.1	60.8	47.7	42.4	23.2	7.4	10.1	4.2
1981	31.1	46.2	41.7	51.7	67.2	70.6	58.4	40.2	18.5	5.7	4.4
1982	27.7	58.9	45.1	42.2	71.5	75.0	39.6	20.1	10.4	2.7	0.5
1983	56.2	39.6	75.9	53.5	53.5	77.1	57.9	32.3	16.5	5.2	2.9
1984	13.2	26.3	34.0	70.5	72.2	94.1	107.8	102.1	56.5	23.6	11.3
1985	36.9	52.1	107.2	106.0	127.9	108.8	108.5	103.9	66.1	29.5	15.4
1986	49.3	40.7	67.6	111.6	82.5	74.7	64.3	40.2	56.5	51.8	28.8
1987	18.2	49.4	33.5	49.3	55.4	59.6	73.4	61.0	26.3	40.1	42.3
1988	29.0	57.5	140.5	40.8	71.7	89.4	53.6	104.1	82.1	34.8	176.9
1989	2.5	33.8	47.0	73.1	29.5	20.5	52.0	32.2	45.3	44.5	172.0
1990	8.8	7.0	52.4	29.2	49.4	20.0	18.4	16.9	17.4	23.2	72.2
1991	9.9	62.5	6.5	116.2	28.8	38.8	7.3	18.5	25.5	16.0	60.3
1992	5.9	24.2	83.8	22.5	123.3	29.9	25.0	13.3	15.2	12.7	71.8
1993	12.2	8.1	11.0	57.4	7.4	74.4	16.3	19.9	9.8	15.1	89.9
1994	21.3	33.7	26.8	26.9	127.5	3.2	90.8	9.7	33.9	13.7	85.6
1995	27.7	46.3	21.0	11.2	13.7	83.3	1.8	103.9	9.7	16.9	69.4
1996	13.1	41.1	43.8	19.4	15.5	25.9	74.2	14.3	75.4	10.6	73.6
1997	19.5	25.2	63.6	40.2	27.4	38.5	29.8	114.7	14.3	63.5	114.4
1998	12.2	13.2	15.7	33.2	28.6	20.0	15.8	16.8	28.2	15.3	100.3
1999	2.77	6.97	7.20	7.59	24.45	18.68	10.29	11.66	14.69	20.14	66.89
2000	1.28	7.72	24.69	10.50	11.66	29.30	25.37	19.02	8.89	20.06	21.35
2001	3.83	7.71	11.48	21.08	15.04	11.35	18.60	15.31	13.81	7.37	9.11
2002	2.88	9.67	12.35	16.72	31.51	14.74	10.74	18.97	13.15	7.62	74.66

Table 4.4—Yellowfin sole population numbers-at-age estimated from the annual bottom trawl surveys, 1982-2002.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1982	123.9	363.4	742.8	2882.0	3155.6	2408.1	3193.9	1445.1	1556.8	1258.3	1140.6	863.8	531.6	163.8	73.6	90.3
1983	0.0	6.5	142.0	378.6	1659.5	3495.2	1836.1	2388.3	1786.5	1596.7	2079.7	1576.7	771.9	751.4	154.1	114.3
1984	0.0	115.7	494.3	577.0	957.6	1554.7	1765.8	1832.8	1982.2	1759.3	953.2	1018.8	723.4	580.1	310.6	251.4
1985	0.0	43.2	241.9	762.1	1040.2	619.0	1206.2	1353.3	787.5	904.7	846.5	568.1	519.5	448.5	295.5	177.8
1986	0.0	35.2	66.9	310.9	698.3	1297.7	535.4	888.1	787.9	693.1	482.5	507.7	302.1	450.0	212.2	496.4
1987	0.0	6.4	102.2	210.9	1554.7	932.7	1477.6	681.6	650.0	818.8	534.9	552.6	319.4	381.2	392.2	1199.0
1988	1.1	4.0	32.0	782.6	133.7	2997.0	1524.3	1271.8	319.0	500.8	446.7	464.6	821.5	547.6	290.8	1.8
1989	0.0	17.0	45.6	336.8	1848.0	504.1	3244.5	1350.7	979.0	255.0	280.1	503.4	351.8	540.7	267.2	1296.0
1990	0.0	29.1	116.6	220.9	637.7	1947.2	386.5	2400.2	726.2	746.4	141.6	137.6	174.9	102.4	286.1	1003.6
1991	0.0	12.9	229.3	594.0	256.3	718.7	1933.1	207.1	2423.2	535.7	764.6	142.8	196.5	137.6	164.9	1220.9
1992	0.0	12.7	281.7	670.1	854.0	386.5	436.9	1522.3	183.4	1526.2	232.2	467.1	128.0	133.9	203.9	1149.5
1993	0.0	52.8	180.6	610.3	1300.3	828.2	548.0	471.7	2418.5	147.8	1725.1	226.0	223.0	119.5	67.9	1059.6
1994	4.2	75.2	165.8	388.8	944.6	1857.4	1210.8	789.0	475.3	1992.2	25.7	1137.9	89.7	405.7	153.5	434.5
1995	0.0	18.9	321.7	408.2	451.4	1555.6	1192.1	368.7	314.5	99.9	1111.2	33.9	1163.4	153.2	104.5	929.9
1996	0.0	92.3	248.6	1649.8	536.8	513.3	877.8	879.0	555.1	295.4	299.6	1026.4	181.2	1115.8	179.6	1151.4
1997	0.0	37.7	541.6	927.9	1522.9	437.0	422.7	952.2	473.7	307.9	390.5	292.4	1014.1	122.7	578.4	948.9
1998	0.0	58.9	153.2	829.3	989.5	1732.4	418.8	429.9	574.2	685.3	715.0	320.6	333.6	452.9	180.0	1974.4
1999	0.0	8.8	169.1	343.9	402.9	430.5	1307.5	250.5	201.6	555.4	460.8	261.7	126.2	131.3	296.2	1974.4
2000	0.0	24.5	134.8	527.5	417.2	594.2	791.4	1020.8	268.9	384.0	320.1	344.4	278.8	264.3	233.1	1314.5
2001	0.0	1.3	146.4	376.7	1159.0	637.1	750.7	789.3	1174.6	493.1	281.5	406.5	216.7	227.6	302.5	1037.7
2002	0.0	70.4	201.7	326.9	590.9	1500.2	689.1	602.6	473.8	906.0	391.1	225.7	555.0	251.3	297.3	1268.7

Table 4.5--Female yellowfin sole proportion mature at age from Nichol (1994).

Age	Proportion mature
1	0
2	0
3	.001
4	.004
5	.008
6	.020
7	.046
8	.104
9	.217
10	.397
11	.612
12	.790
13	.899
14	.955
15	.981
16	.992
17	.997
18	1.000
19	1.000
20	1.000

Table 4.6--Key equations used in the population dynamics model.

$N_{t,1} = R_t = R_0 e^{\tau_t}, \quad \tau_t \sim N(0, \delta^2_R)$	Recruitment 1956-75
$N_{t,1} = R_t = R_\gamma e^{\tau_t}, \quad \tau_t \sim N(0, \delta^2_R)$	Recruitment 1976-96
$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}} (1 - e^{-z_{t,a}}) N_{t,a}$	Catch in year t for age a fish
$N_{t+1,a+1} = N_{t,a} e^{-z_{t,a}}$	Numbers of fish in year $t+1$ at age a
$N_{t+1,A} = N_{t,A-1} e^{-z_{t,A-1}} + N_{t,A} e^{-z_{t,A}}$	Numbers of fish in the “plus group”
$S_t = \sum N_{t,a} W_{t,a} \phi_a$	Spawning biomass
$Z_{t,a} = F_{t,a} + M$	Total mortality in year t at age a
$F_{t,a} = s_a \mu^F \exp^{\varepsilon^F_t}, \quad \varepsilon^F_t \sim N(0, \sigma^2_F)$	Fishing mortality
$s_a = \frac{1}{1 + (e^{-\alpha + \beta a})}$	Age-specific fishing selectivity
$C_t = \sum C_{t,a}$	Total catch in numbers
$P_{t,a} = C_{t,a} / C_t$	Proportion at age in catch
$SurB_t = q \sum N_{t,a} W_{t,a} v_a$	Survey biomass
$L = \sum_{t,a} m_t p_{t,a} \ln \frac{\hat{p}_{t,a}}{P_{t,a}} + (-0.5) \sum_t \left[\left(\ln \frac{SurB_t}{\hat{SurB}_t} \right)^2 / \sigma_t^2 - \ln \sigma_t^2 \right]$	Total log likelihood

Table 4.7--Variables used in the population dynamics model.

Variables	
R_t	Age 1 recruitment in year t
R_0	Geometric mean value of age 1 recruitment, 1956-75
R_γ	Geometric mean value of age 1 recruitment, 1976-96
τ_t	Recruitment deviation in year t
$N_{t,a}$	Number of fish in year t at age a
$C_{t,a}$	Catch numbers of fish in year t at age a
$P_{t,a}$	Proportion of the numbers of fish age a in year t
C_t	Total catch numbers in year t
$W_{t,a}$	Mean body weight (kg) of fish age a in year t
ϕ_a	Proportion of mature females at age a
$F_{t,a}$	Instantaneous annual fishing mortality of age a fish in year t
M	Instantaneous natural mortality, assumed constant over all ages and years
$Z_{t,a}$	Instantaneous total mortality for age a fish in year t
s_a	Age-specific fishing gear selectivity
μ^F	Median year-effect of fishing mortality
ε_t^F	The residual year-effect of fishing mortality
ν_a	Age-specific survey selectivity
α	Slope parameter in the logistic selectivity equation
β	Age at 50% selectivity parameter in the logistic selectivity equation
σ_t	Standard error of the survey biomass in year t

Table 4.8--Model estimates of yellowfin sole fishing mortality and exploitation rate (catch/total biomass).

Year	Full selection F	Exploitation Rate
1954	0.010	0.008
1955	0.012	0.009
1956	0.021	0.014
1957	0.021	0.014
1958	0.040	0.024
1959	0.183	0.098
1960	0.564	0.252
1961	1.075	0.381
1962	1.616	0.419
1963	0.495	0.123
1964	0.592	0.152
1965	0.238	0.073
1966	0.365	0.130
1967	0.566	0.207
1968	0.298	0.119
1969	0.653	0.231
1970	0.637	0.202
1971	1.020	0.246
1972	0.350	0.074
1973	0.509	0.099
1974	0.216	0.045
1975	0.243	0.057
1976	0.155	0.042
1977	0.120	0.037
1978	0.228	0.077
1979	0.135	0.051
1980	0.097	0.042
1981	0.091	0.044
1982	0.078	0.041
1983	0.078	0.045
1984	0.108	0.064
1985	0.153	0.091
1986	0.146	0.086
1987	0.133	0.076
1988	0.173	0.096
1989	0.122	0.069
1990	0.062	0.037
1991	0.069	0.043
1992	0.112	0.073
1993	0.075	0.051
1994	0.105	0.070
1995	0.095	0.063
1996	0.103	0.068
1997	0.153	0.100
1998	0.092	0.060
1999	0.063	0.041
2000	0.080	0.051
2001	0.061	0.040
2002	0.070	0.046
2003		0.047

Table 4.9--Model estimates of yellowfin sole age-specific selectivities for survey and fishery data

Age	Fishery (1964-2002)	Survey (1982-2002)
1	0.000	0.002
2	0.001	0.007
3	0.002	0.032
4	0.006	0.130
5	0.016	0.405
6	0.043	0.756
7	0.110	0.934
8	0.255	0.985
9	0.486	0.997
10	0.724	0.999
11	0.879	1.000
12	0.952	1.000
13	0.982	1.000
14	0.982	1.000
15	0.982	1.000
16	0.982	1.000
17	0.982	1.000
18	0.982	1.000
19	0.982	1.000
20	0.982	1.000

Table 4.10—Model estimates of yellowfin sole age 2+ total biomass and begin-year Female spawning biomass from the 2002 and 2003 stock assessments.

Year	2003	Age 2+ Total Biomass	2002	Age 2+ Total Biomass
	Assessment Female Spawning Biomass		Assessment Female Spawning Biomass	
1964	71,453	732,312	71,975	732,648
1965	74,133	736,371	74,509	735,777
1966	99,059	789,963	99,406	788,293
1967	116,139	782,875	116,434	779,899
1968	110,701	708,399	110,832	703,994
1969	121,446	722,815	121,354	717,128
1970	97,689	658,497	97,217	651,837
1971	80,364	652,687	79,500	645,348
1972	52,325	647,531	51,216	640,203
1973	60,102	793,780	58,617	785,769
1974	65,854	935,733	64,121	927,304
1975	90,663	1,142,160	88,568	1,133,200
1976	121,983	1,345,530	119,562	1,336,130
1977	168,300	1,571,590	165,511	1,561,680
1978	227,147	1,799,720	224,009	1,789,190
1979	272,360	1,933,070	269,069	1,921,810
1980	338,735	2,089,190	335,236	2,076,780
1981	417,544	2,232,510	413,845	2,218,580
1982	495,766	2,337,300	491,877	2,321,480
1983	574,099	2,429,430	569,993	2,411,280
1984	643,398	2,496,160	638,951	2,475,200
1985	681,397	2,504,590	676,426	2,480,370
1986	674,048	2,438,100	668,321	2,410,270
1987	654,221	2,380,580	647,567	2,349,050
1988	634,249	2,335,200	626,497	2,300,020
1989	591,257	2,229,570	582,216	2,190,980
1990	585,851	2,185,250	575,511	2,143,960
1991	619,086	2,203,180	607,345	2,159,720
1992	649,794	2,187,250	636,557	2,142,000
1993	648,140	2,095,960	633,416	2,049,380
1994	656,543	2,052,570	640,517	2,005,660
1995	633,694	1,964,910	616,620	1,918,910
1996	609,042	1,894,580	591,318	1,850,430
1997	578,813	1,817,600	560,805	1,775,610
1998	527,485	1,690,210	509,377	1,650,310
1999	509,300	1,643,890	491,235	1,606,790
2000	503,990	1,628,580	486,346	1,593,820
2001	494,597	1,599,070	477,860	1,564,820
2002	493,675	1,586,250	478,506	1,551,720
2003	489,761	1,571,580		

Table 4.11—Model estimates of yellowfin sole population number at age (billions) for 1954- 2003.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	2.87	4.03	2.19	0.90	0.44	0.38	0.36	0.35	0.34	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.32	0.33	0.33
1955	1.37	2.55	3.57	1.94	0.80	0.39	0.34	0.32	0.31	0.30	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.58
1956	0.89	1.21	2.26	3.17	1.72	0.71	0.35	0.30	0.28	0.27	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.75
1957	3.11	0.79	1.07	2.00	2.81	1.53	0.63	0.31	0.26	0.25	0.24	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.87
1958	2.31	2.76	0.70	0.95	1.78	2.49	1.35	0.55	0.27	0.23	0.22	0.21	0.20	0.19	0.19	0.19	0.19	0.19	0.19	0.95
1959	1.75	2.04	2.45	0.62	0.84	1.58	2.21	1.19	0.49	0.24	0.20	0.19	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.97
1960	1.84	1.55	1.81	2.17	0.55	0.75	1.39	1.92	1.01	0.39	0.18	0.15	0.14	0.13	0.13	0.12	0.12	0.12	0.12	0.84
1961	1.08	1.63	1.37	1.61	1.92	0.48	0.65	1.16	1.47	0.68	0.23	0.10	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.49
1962	1.84	0.96	1.45	1.22	1.42	1.67	0.41	0.51	0.78	0.77	0.28	0.08	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.17
1963	0.93	1.63	0.85	1.28	1.07	1.22	1.38	0.30	0.30	0.32	0.21	0.06	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.03
1964	0.87	0.82	1.45	0.75	1.13	0.94	1.06	1.16	0.24	0.21	0.20	0.12	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.02
1965	1.22	0.77	0.73	1.28	0.66	0.99	0.81	0.88	0.89	0.16	0.12	0.10	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.01
1966	1.45	1.08	0.69	0.65	1.14	0.59	0.87	0.70	0.74	0.70	0.12	0.09	0.07	0.04	0.01	0.00	0.00	0.00	0.00	0.01
1967	2.38	1.28	0.96	0.61	0.57	1.00	0.51	0.74	0.57	0.55	0.48	0.08	0.05	0.05	0.03	0.01	0.00	0.00	0.00	0.01
1968	2.57	2.11	1.14	0.85	0.54	0.50	0.87	0.43	0.57	0.38	0.32	0.26	0.04	0.03	0.02	0.01	0.00	0.00	0.00	0.00
1969	2.50	2.28	1.87	1.01	0.75	0.47	0.44	0.74	0.35	0.44	0.27	0.22	0.17	0.03	0.02	0.02	0.01	0.00	0.00	0.00
1970	3.44	2.22	2.02	1.65	0.89	0.66	0.41	0.36	0.56	0.23	0.24	0.14	0.10	0.08	0.01	0.01	0.01	0.00	0.00	0.00
1971	4.18	3.05	1.96	1.79	1.46	0.78	0.57	0.34	0.27	0.36	0.13	0.12	0.07	0.05	0.04	0.01	0.00	0.00	0.00	0.00
1972	4.05	3.71	2.70	1.74	1.58	1.28	0.66	0.45	0.23	0.15	0.15	0.05	0.04	0.02	0.02	0.01	0.00	0.00	0.00	0.00
1973	3.60	3.59	3.29	2.39	1.54	1.39	1.11	0.57	0.37	0.17	0.10	0.10	0.03	0.03	0.01	0.01	0.01	0.00	0.00	0.00
1974	3.93	3.19	3.18	2.91	2.12	1.35	1.21	0.93	0.44	0.25	0.11	0.06	0.05	0.02	0.01	0.01	0.01	0.00	0.00	0.00
1975	4.71	3.49	2.83	2.82	2.58	1.87	1.19	1.05	0.78	0.35	0.19	0.08	0.04	0.04	0.01	0.01	0.01	0.00	0.00	0.00
1976	3.00	4.18	3.09	2.51	2.50	2.28	1.64	1.03	0.87	0.62	0.26	0.14	0.05	0.03	0.03	0.01	0.01	0.00	0.00	0.00
1977	3.49	2.66	3.70	2.74	2.22	2.21	2.01	1.43	0.88	0.72	0.49	0.20	0.11	0.04	0.02	0.02	0.01	0.01	0.00	0.00
1978	2.32	3.10	2.36	3.28	2.43	1.97	1.95	1.76	1.23	0.73	0.58	0.39	0.16	0.08	0.03	0.02	0.02	0.00	0.00	0.01
1979	1.55	2.06	2.75	2.09	2.91	2.15	1.73	1.69	1.47	0.98	0.55	0.42	0.28	0.11	0.06	0.02	0.01	0.01	0.00	0.01
1980	2.87	1.37	1.82	2.44	1.85	2.57	1.89	1.51	1.45	1.22	0.79	0.43	0.33	0.22	0.09	0.05	0.02	0.01	0.01	0.01
1981	2.07	2.55	1.22	1.62	2.16	1.64	2.27	1.66	1.31	1.22	1.01	0.64	0.35	0.27	0.17	0.07	0.04	0.01	0.01	0.01
1982	5.63	1.83	2.26	1.08	1.43	1.91	1.45	2.00	1.44	1.11	1.02	0.83	0.52	0.28	0.22	0.14	0.06	0.03	0.01	0.02
1983	0.96	4.99	1.63	2.00	0.96	1.27	1.69	1.27	1.74	1.23	0.93	0.84	0.68	0.43	0.23	0.18	0.12	0.05	0.02	0.02
1984	4.59	0.85	4.43	1.44	1.78	0.85	1.12	1.49	1.11	1.48	1.03	0.77	0.69	0.56	0.35	0.19	0.15	0.10	0.04	0.04
1985	1.46	4.07	0.76	3.93	1.28	1.57	0.75	0.98	1.28	0.93	1.22	0.83	0.62	0.55	0.45	0.28	0.15	0.12	0.08	0.06
1986	1.19	1.29	3.61	0.67	3.48	1.13	1.39	0.65	0.84	1.06	0.74	0.94	0.64	0.47	0.42	0.34	0.21	0.12	0.09	0.11
1987	1.64	1.05	1.14	3.20	0.59	3.08	1.00	1.21	0.56	0.69	0.84	0.58	0.73	0.49	0.36	0.32	0.26	0.16	0.09	0.15
1988	2.20	1.45	0.93	1.02	2.83	0.53	2.71	0.87	1.04	0.46	0.56	0.67	0.45	0.57	0.38	0.28	0.25	0.20	0.13	0.19
1989	2.22	1.96	1.29	0.83	0.90	2.51	0.46	2.36	0.74	0.85	0.36	0.43	0.50	0.34	0.42	0.29	0.21	0.19	0.15	0.24
1990	1.00	1.97	1.73	1.14	0.73	0.80	2.21	0.41	2.03	0.62	0.69	0.29	0.34	0.39	0.27	0.33	0.22	0.17	0.15	0.31
1991	1.05	0.89	1.75	1.54	1.01	0.65	0.70	1.95	0.35	1.75	0.52	0.58	0.24	0.28	0.33	0.22	0.28	0.19	0.14	0.38
1992	2.69	0.93	0.79	1.55	1.36	0.90	0.57	0.62	1.70	0.30	1.47	0.44	0.48	0.20	0.23	0.27	0.18	0.23	0.16	0.43
1993	1.48	2.38	0.83	0.70	1.38	1.21	0.79	0.50	0.53	1.43	0.25	1.19	0.35	0.38	0.16	0.18	0.22	0.15	0.18	0.46
1994	1.39	1.31	2.11	0.73	0.62	1.22	1.07	0.70	0.44	0.46	1.20	0.21	0.98	0.29	0.31	0.13	0.15	0.18	0.12	0.53
1995	1.18	1.23	1.16	1.87	0.65	0.55	1.08	0.94	0.60	0.37	0.38	0.97	0.17	0.78	0.23	0.25	0.10	0.12	0.14	0.52
1996	2.07	1.05	1.09	1.03	1.66	0.57	0.48	0.94	0.81	0.51	0.31	0.31	0.79	0.13	0.63	0.19	0.20	0.08	0.10	0.54
1997	1.13	1.84	0.93	0.97	0.91	1.47	0.51	0.42	0.82	0.68	0.42	0.25	0.25	0.63	0.11	0.51	0.15	0.16	0.07	0.51
1998	1.15	1.00	1.63	0.82	0.86	0.81	1.30	0.44	0.36	0.67	0.54	0.33	0.19	0.19	0.48	0.08	0.39	0.11	0.12	0.44
1999	1.54	1.02	0.89	1.45	0.73	0.76	0.71	1.14	0.38	0.31	0.56	0.44	0.26	0.15	0.15	0.39	0.07	0.31	0.09	0.46
2000	1.81	1.36	0.91	0.79	1.28	0.65	0.67	0.63	0.99	0.33	0.26	0.47	0.37	0.22	0.13	0.13	0.32	0.06	0.26	0.46
2001	1.70	1.60	1.21	0.80	0.70	1.14	0.57	0.59	0.55	0.85	0.28	0.21	0.38	0.30	0.18	0.11	0.10	0.27	0.05	0.59
2002	1.90	1.51	1.42	1.07	0.71	0.62	1.00	0.50	0.52	0.47	0.72	0.23	0.18	0.32	0.25	0.15	0.09	0.09	0.22	0.53
2003	1.94	1.69	1.34	1.26	0.95	0.63	0.55	0.88	0.44	0.44	0.40	0.60	0.19	0.15	0.27	0.21	0.12	0.07	0.07	0.62

Table 4.12—Model estimates of yellowfin sole age 5 recruitment from the 2002 and 2003 stock assessments.

Year class	2003 Assessment	2002 Assessment
1959	1,132	1,129
1960	664	651
1961	1,137	1,129
1962	572	556
1963	538	527
1964	750	740
1965	891	882
1966	1,462	1,454
1967	1,579	1,573
1968	1,539	1,534
1969	2,117	2,113
1970	2,580	2,575
1971	2,499	2,491
1972	2,223	2,217
1973	2,431	2,422
1974	2,908	2,894
1975	1,853	1,837
1976	2,159	2,138
1977	1,433	1,411
1978	955	932
1979	1,776	1,746
1980	1,277	1,250
1981	3,479	3,417
1982	594	545
1983	2,834	2,777
1984	899	836
1985	733	679
1986	1,012	968
1987	1,363	1,375
1988	1,375	1,352
1989	618	595
1990	649	575
1991	1,662	1,776
1992	915	984
1993	857	922
1994	730	688
1995	1,282	1,150
1996	699	799
1997	714	
1998	950	

Table 4.13. Projections of yellowfin sole female spawning biomass (1,000s t), catch (1,000s mt) and full selection fishing mortality rate for seven future harvest scenarios.

Scenarios 1 and 2 Maximum permissible ABC				Scenario 3 1/2 Max permissible ABC			
Year	Female spawning biomass	catch	F	Year	Female spawning biomass	catch	F
2003	460.293	72.270	0.07	2003	460.293	72.273	0.07
2004	446.384	113.518	0.12	2004	454.479	58.198	0.06
2005	421.520	107.371	0.12	2005	451.933	57.790	0.06
2006	399.570	101.881	0.12	2006	449.712	57.337	0.06
2007	380.514	95.125	0.11	2007	447.275	57.136	0.06
2008	366.413	89.391	0.11	2008	445.865	57.447	0.06
2009	358.373	86.759	0.11	2009	447.030	58.156	0.06
2010	356.380	86.808	0.10	2010	452.348	59.291	0.06
2011	359.058	88.816	0.11	2011	461.777	60.787	0.06
2012	363.142	91.270	0.11	2012	471.999	62.231	0.06
2013	368.171	93.874	0.11	2013	483.192	63.642	0.06
2014	373.059	95.917	0.11	2014	494.268	64.956	0.06
2015	377.800	97.516	0.11	2015	505.358	66.221	0.06
2016	381.404	98.539	0.11	2016	514.685	67.270	0.06
Scenario 4 Harvest at average F over the past 5 years				Scenario 5 No fishing			
Year	Female spawning biomass	catch	F	Year	Female spawning biomass	catch	F
2003	460.293	72.271	0.07	2003	460.293	0	0
2004	452.300	73.274	0.07	2004	462.727	0	0
2005	443.580	71.818	0.07	2005	484.629	0	0
2006	435.679	70.403	0.07	2006	506.520	0	0
2007	428.147	69.415	0.07	2007	527.292	0	0
2008	422.304	69.173	0.07	2008	547.608	0	0
2009	419.665	69.522	0.07	2009	568.788	0	0
2010	421.593	70.465	0.07	2010	593.043	0	0
2011	427.831	71.893	0.07	2011	621.103	0	0
2012	435.213	73.309	0.07	2012	648.711	0	0
2013	443.762	74.715	0.07	2013	676.657	0	0
2014	452.391	76.030	0.07	2014	703.732	0	0
2015	461.124	77.298	0.07	2015	730.585	0	0
2016	468.400	78.337	0.07	2016	754.196	0	0
Scenario 6 Determination of whether yellowfin sole are currently overfished B35=341.600				Scenario 7 Determination of whether the stock is approaching an overfished condition B35=341.600			
Year	Female spawning biomass	catch	F	Year	Female spawning biomass	catch	F
2003	460.293	72.270	0.07	2003	460.293	72.272	0.07
2004	443.212	134.709	0.14	2004	446.384	113.517	0.12
2005	410.044	124.991	0.14	2005	421.519	107.371	0.12
2006	381.725	113.938	0.13	2006	396.738	120.905	0.14
2007	358.936	101.445	0.13	2007	370.711	107.971	0.13
2008	343.250	94.181	0.12	2008	352.006	98.786	0.12
2009	334.484	90.871	0.12	2009	340.851	94.112	0.12
2010	332.134	90.744	0.12	2010	336.643	93.015	0.12
2011	334.508	92.827	0.12	2011	337.615	94.430	0.12
2012	338.382	95.454	0.12	2012	340.403	96.590	0.12
2013	343.126	98.356	0.12	2013	344.370	99.077	0.12
2014	347.590	100.919	0.12	2014	348.290	101.265	0.12
2015	351.641	103.047	0.12	2015	352.028	103.190	0.12
2016	354.432	104.409	0.12	2016	354.692	104.467	0.12

Table 4-14. Yellowfin catch and bycatch from 1992-2002 estimated from a blend of regional office reported catch and observer sampling of the catch.

Species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Grand Total
Walleye Pollock	13,100	15,253	33,200	27,041	22,254	24,100	15,335	8,701	13,425	16,502	14,489	203,402
Arrowtooth Flounder	366	1,017	1,595	346	820	386	2,382	1,627	1,998	1,845	998	13,381
Pacific Cod	8,700	8,723	16,415	13,181	8,684	12,825	10,224	4,380	5,192	6,531	6,259	101,115
Groundfish, General	7,990	3,847	3,983	2,904	2,565	4,755	3,580	2,524	3,541	3,936	2,678	42,302
Rock Sole	14,646	7,301	8,097	7,486	12,903	16,693	9,825	10,773	7,345	5,810	10,665	111,544
Flathead Sole		1,198	2,491	3,929	3,166	3,896	5,328	2,303	2,644	3,231	2,190	30,377
Sablefish	0	0		0	0	0	0	4	0	0		5
Atka Mackerel	1	0			0	0	1	33	0	0	0	36
Pacific Ocean Perch	0	5		0		0	1	12	1	1	1	22
Rex Sole			1	1		0	20	36	1	2	0	61
Flounder, General	16,826	6,615	7,080	11,092	10,372	10,743	6,362	8,812	7,913	4,854	378	91,049
Squid	0		5	0	11	0	2	1	0	0	0	18
Dover Sole			35									35
Thornyhead					0		1					1
Shortraker/Rougheye	0				1	0	1	15		1		18
Butter Sole			0			3	3		2		7	15
Eulachon smelt								0				0
Starry Flounder		227	106	16	37	124	35	48	71	82	133	880
Northern Rockfish						1	0	0			1	1
Dusky Rockfish								0			0	0
Yellowfin Sole	136,804	91,931	126,163	108,493	112,818	169,661	90,062	62,941	71,479	54,722	66,178	1,091,251
English Sole		1									1	1
Unsp. demersal rockfish						12	0					12
Greenland Turbot	1	5	5	67	8	4	103	70	24	32	2	321
Alaska Plaice		1,579	2,709	1,130	553	6,351	2,758	2,530	2,299	1,905	10,396	32,209
Sculpin, General								215	97	12	1,226	1,549
Skate, General								26	4	21	1,042	1,093
Sharpchin Rockfish								1				1
Bocaccio	0											0
Rockfish, General	0		0	3	23	0	1	3	4	1		35
Octopus								0				0
Smelt, general								0	0	0		0
Chillipepper		1										1
Eels								1	1	0	0	2
Lingcod										2		2
Jellyfish (unspecified)									127	173	161	462
Snails								12	4	0	4	20
Sea cucumber								0	56		0	57
Korean horsehair crab								0	0	0		0
Greenling, General								0	0			0
Shrimp, general								0	0	0	0	0
Grand Total	198,435	137,704	201,884	175,690	174,214	249,557	146,024	105,069	116,226	99,664	116,810	1,721,280

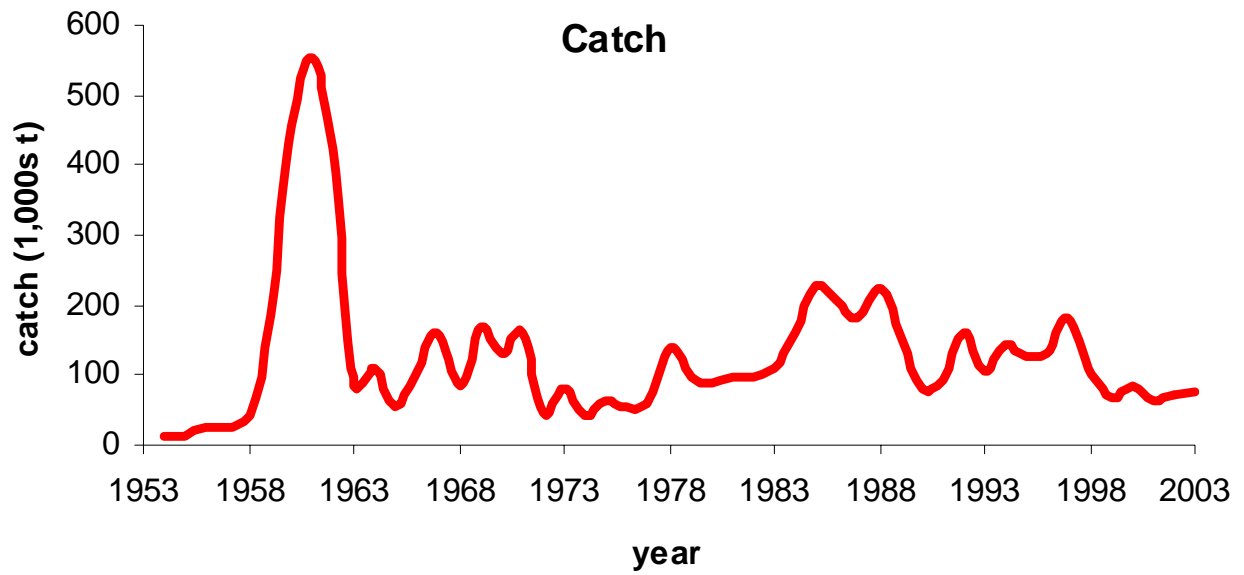


Figure 4.1. Total catch (t) of yellowfin sole 1954-September 27, 2003.

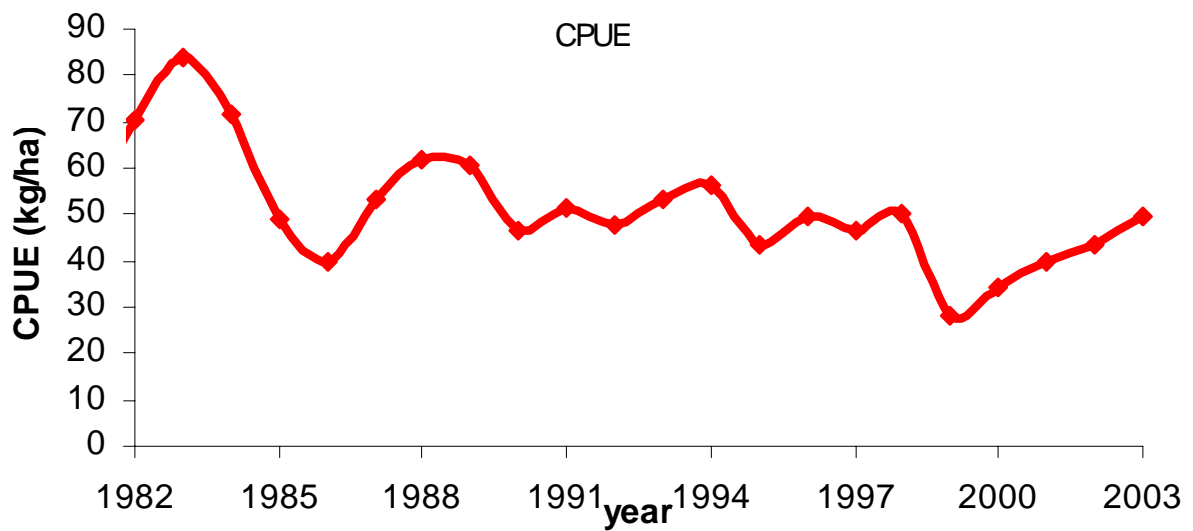


Figure 4.2. Yellowfn sole CPUE (catch per unit effort in kg/ha) from the annual Bering Sea shelf trawl surveys, 1982-2003.

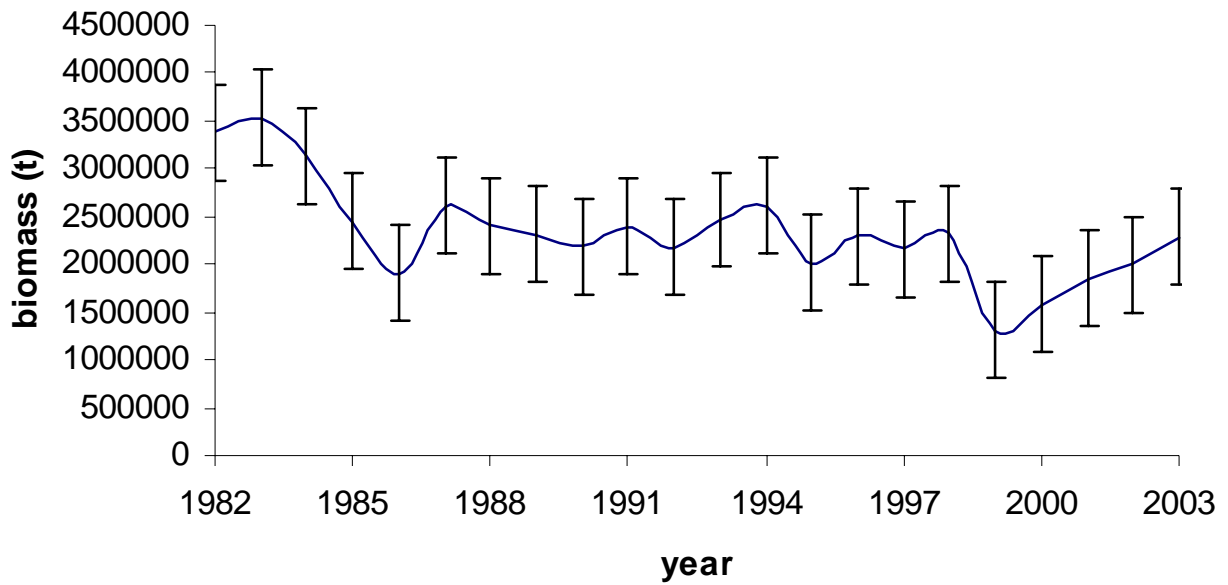


Figure 4.3 Annual bottom trawl survey biomass point-estimates and 95% confidence intervals for yellowfin sole.

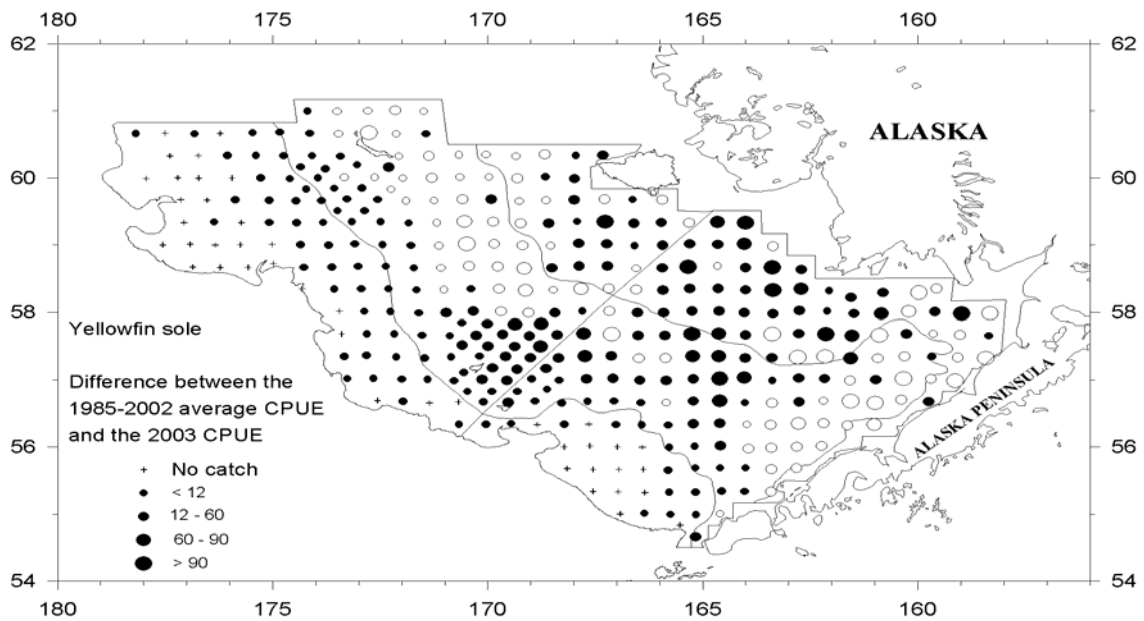


Figure 4.4. Difference between the 1985-2000 average trawl survey CPUE for yellowfin sole and the 2003 survey CPUE. Open circles indicate that the magnitude of the catch was greater in 2003 than the long-term average, closed circles indicate the catch was greater in the long-term average than in 2003.

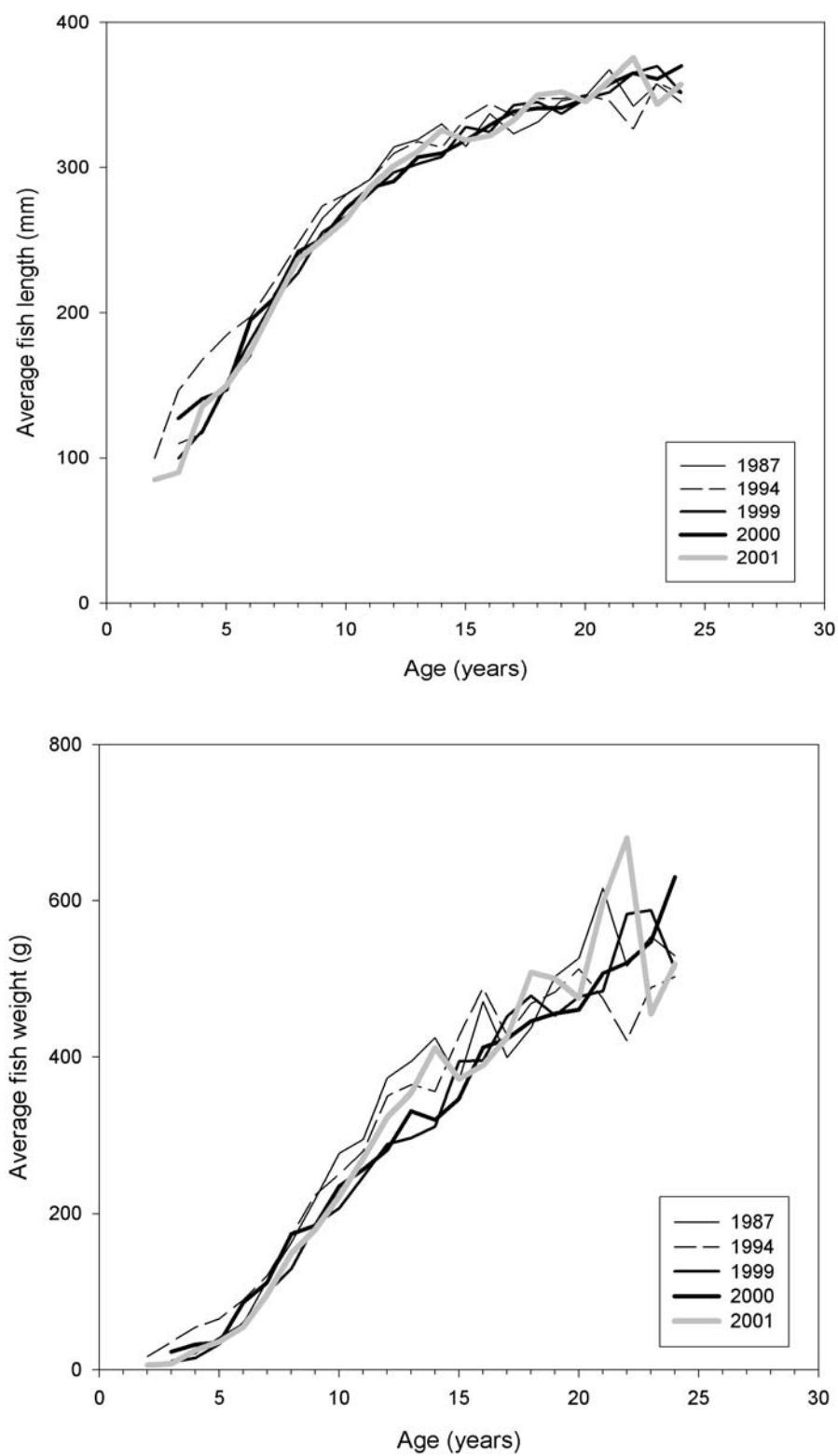


Figure 4.5. Comparison of yellowfin sole length at age (top panel) and weight at age (bottom panel) from biological samples collected in 1987, 1994, 1999, 2000 and 2001.

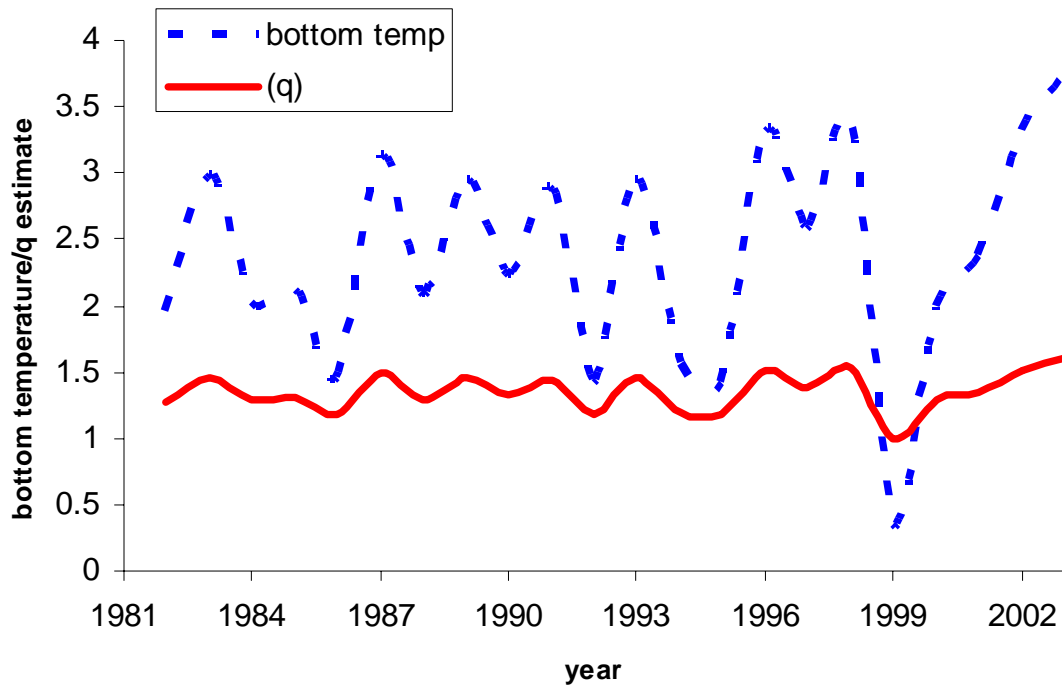


Figure 4.6. Average bottom water temperature from stations less than or equal to 100 m in the Bering Sea trawl survey and the stock assessment model estimate of q for each year 1982-2003.

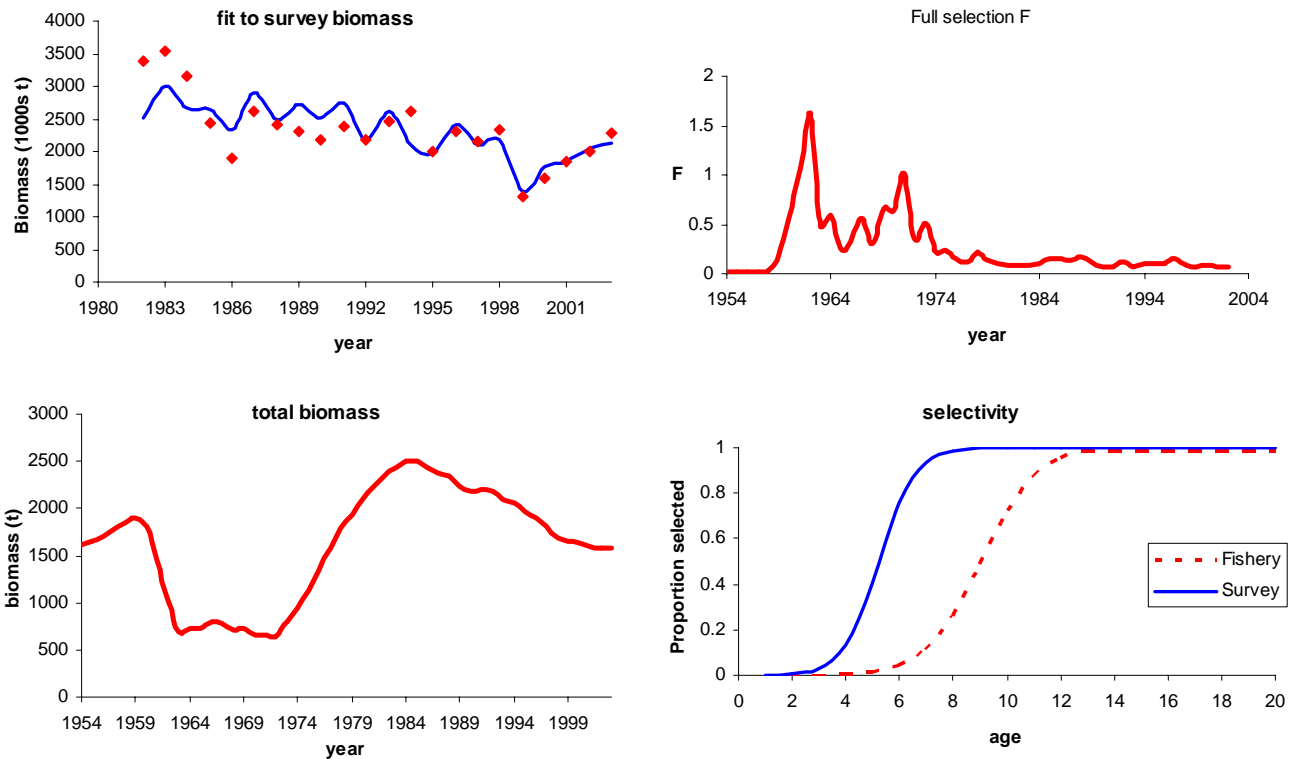


Figure 4.7 Model fit to the survey biomass estimates (top left panel), model estimate of the full selection fishing mortality rate throughout the time-series (top right panel), model estimate of total biomass (bottom left panel) and the model estimate of fishery and survey selectivity (bottom right panel).

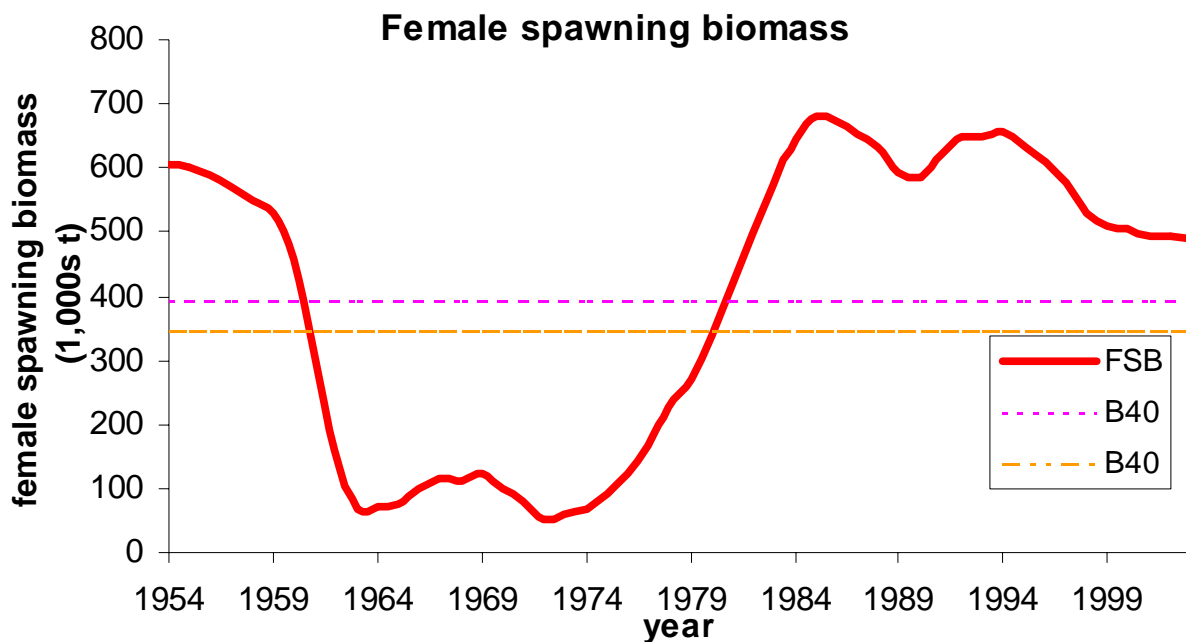


Figure 4.8. Model estimate of yellowfin sole female spawning biomass from 1978-2002 with B40 and B35 levels indicated.

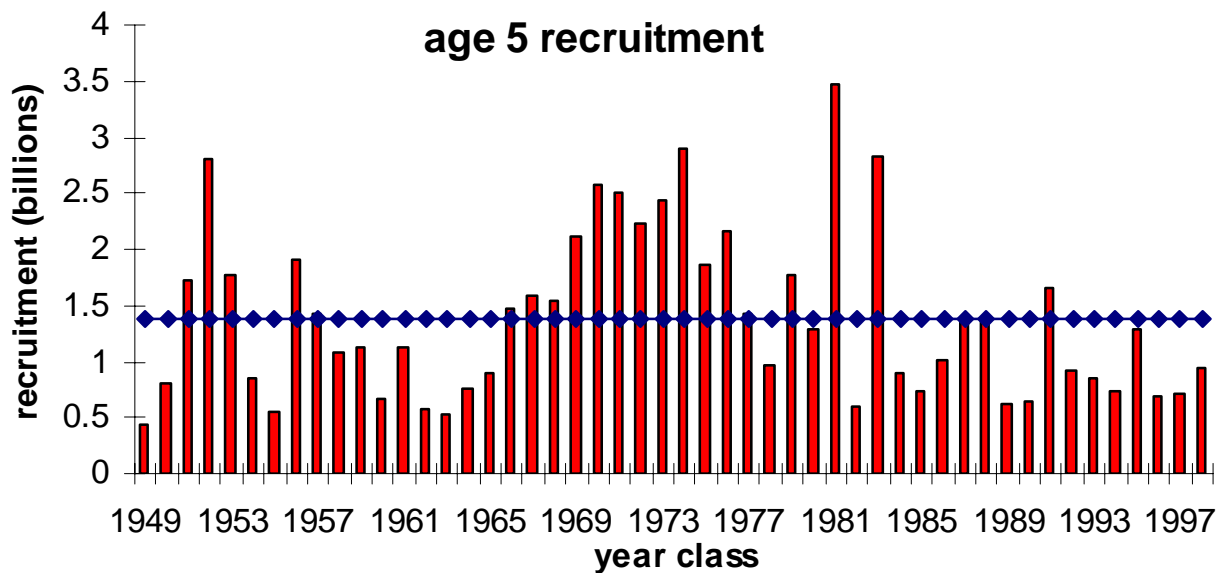


Figure 4.9. Year class strength of age 5 yellowfin sole estimated by the stock assessment model. The dotted line is the average of the estimates from 49 years of recruitment.

All years

Fmsy=0.37

MSY=217,000 t

Bmsy=208,800 t

1978-99

Fmsy=0.22

MSY=150,100

Bmsy=249,800

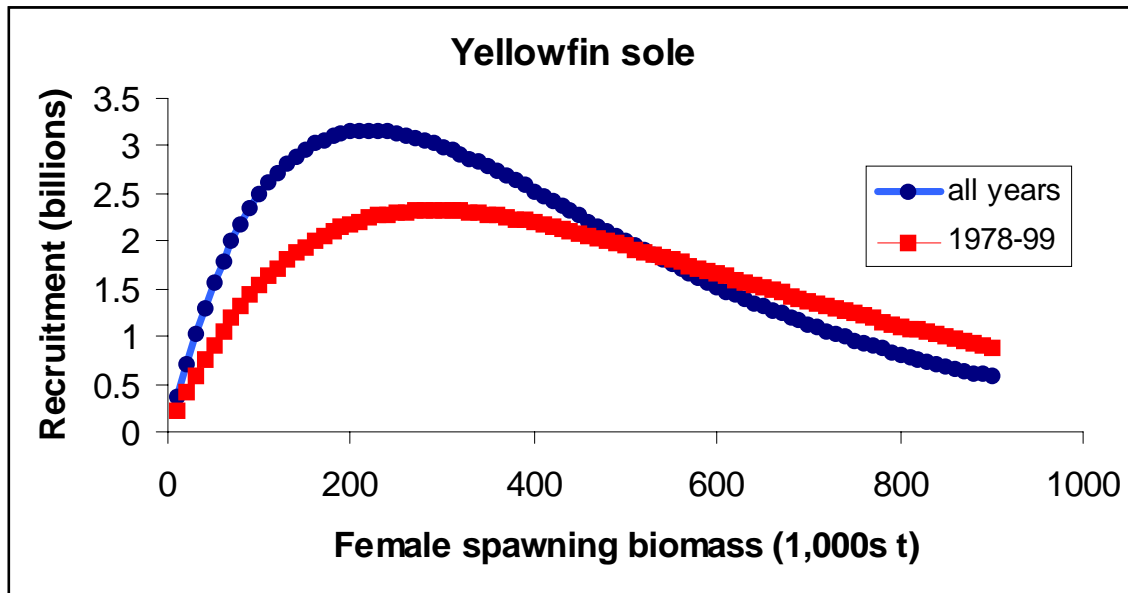


Figure 4.10. Ricker curve fit to yellowfin sole female spawning biomass-age 2 recruitment numbers for two data sets: 1954-99 (all years) and 1978-99.

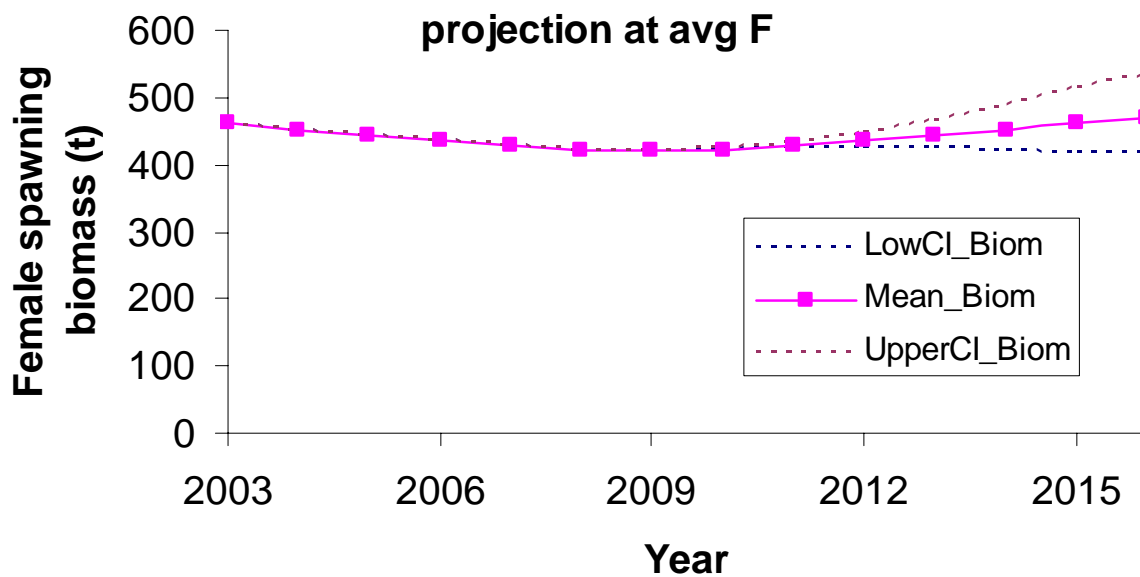


Figure 4.11. Projection of yellowfin sole female spawning biomass (1,000s t) at the average 1998-2002 F level through 2016 with B40 and B35 levels indicated.

Appendix

- 1) 2001 fishery locations by quarter. Catches where yellowfin sole comprised 20% or more of the catch are indicated as darker circles.
- 2) Figures showing the fit of the stock assessment model to the time-series of fishery and trawl survey age compositions (survey and fishery observations are the solid lines).
- 3) Table of yellowfin sole catch from surveys conducted in the eastern Bering Sea and Aleutian Islands area, 1977-2002.
- 4) Table of number of female spawners (millions) estimated by the stock assessment model for each year.
- 5) Selected parameter estimates and their standard deviation from the stock assessment model.

Yellowfin sole fishery catch in 2001

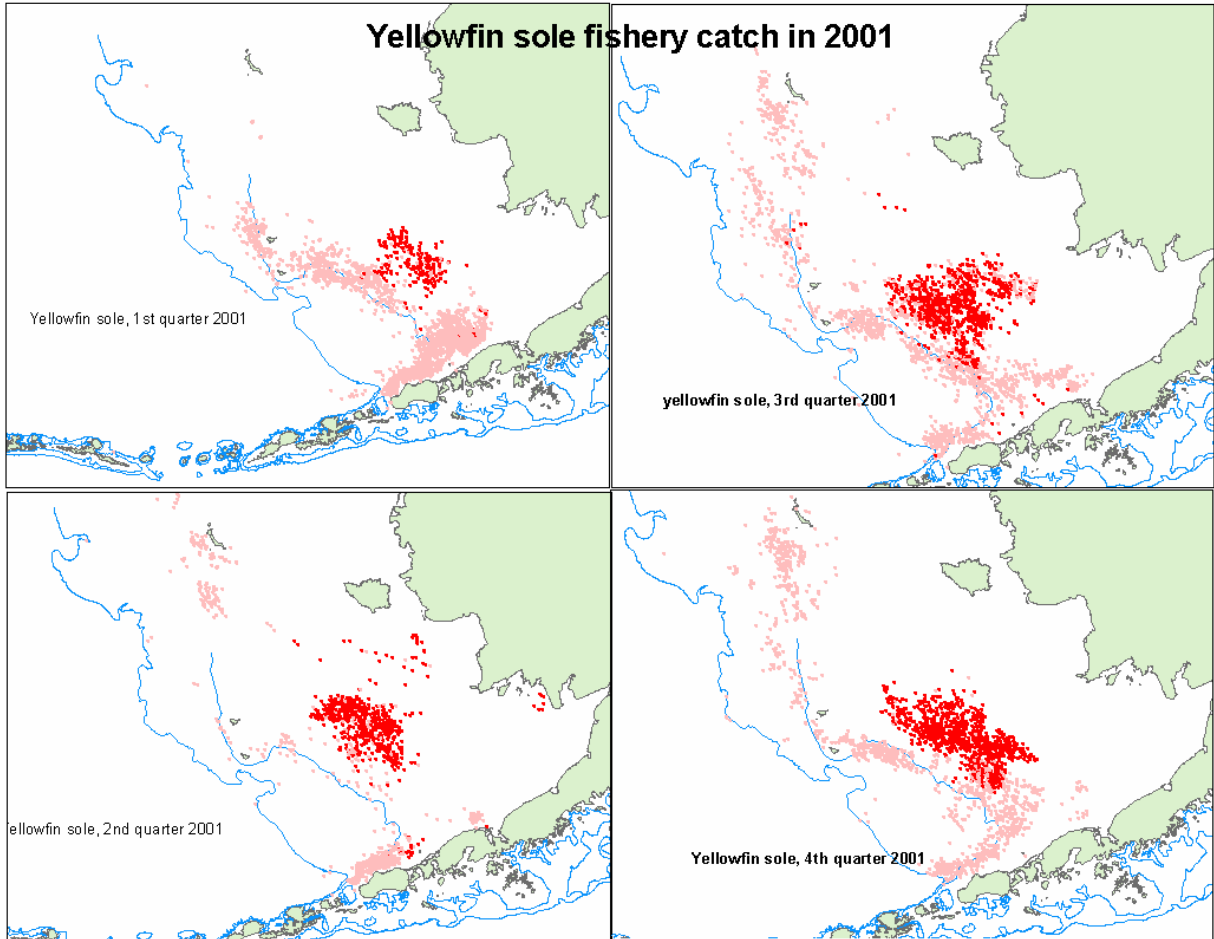
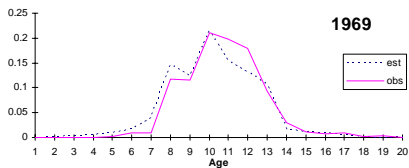
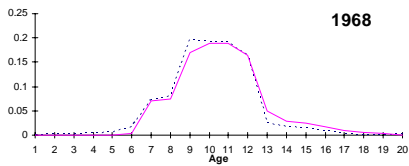
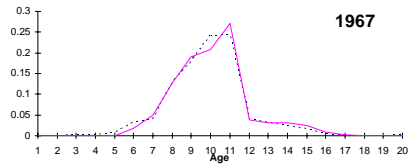
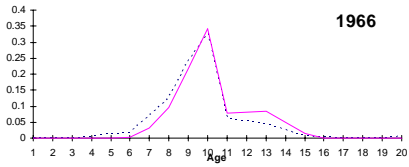
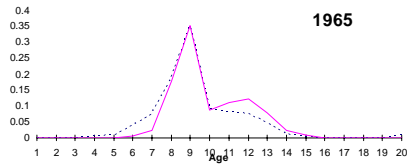
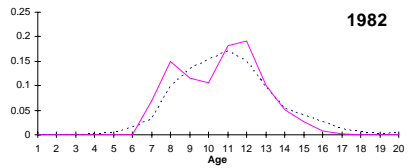
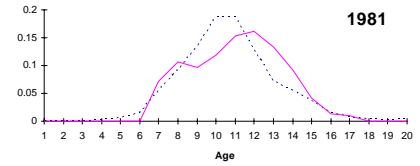
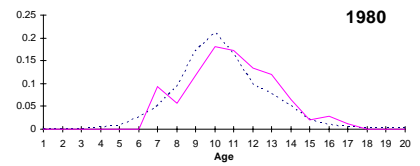
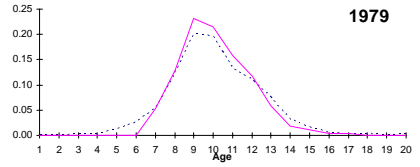
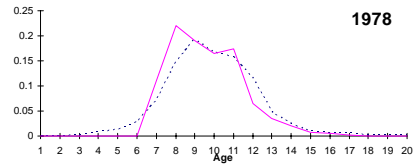
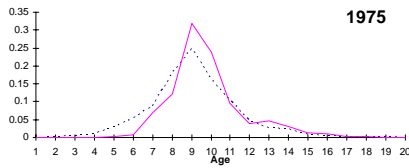
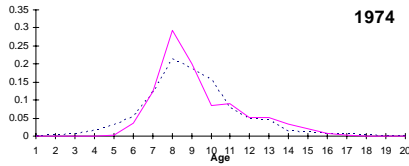
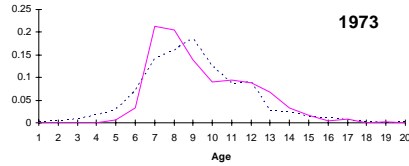
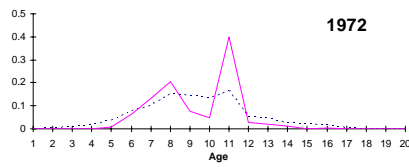
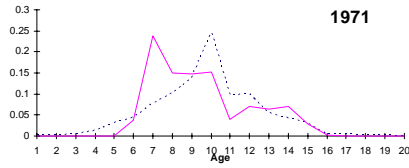


Figure 1 is a line graph titled "1964" showing age-specific incidence rates of dengue fever in Singapore. The x-axis is labeled "Age" and ranges from 1 to 20. The y-axis represents the incidence rate, ranging from 0 to 0.35. Two data series are plotted: a solid magenta line representing the observed incidence and a dashed black line representing the expected incidence. The observed incidence starts at age 3, rises to a peak of approximately 0.28 at age 5, drops to about 0.08 at age 6, then rises to a higher peak of approximately 0.33 at age 8. After age 8, it drops sharply to about 0.08 at age 10, remains relatively stable until age 12, and then declines to near zero by age 15. The expected incidence starts at age 4, rises to a peak of approximately 0.33 at age 8, drops to about 0.12 at age 10, rises to a secondary peak of approximately 0.15 at age 11, and then declines to near zero by age 15. The observed incidence is generally higher than the expected incidence for ages 5 through 12.



1970

Age	Estimated Probability (Solid Magenta)	True Probability (Dashed Black)
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00
5	0.00	0.00
6	0.01	0.01
7	0.04	0.04
8	0.12	0.12
9	0.18	0.24
10	0.06	0.18
11	0.08	0.16
12	0.12	0.10
13	0.08	0.08
14	0.09	0.05
15	0.01	0.01
16	0.00	0.00
17	0.00	0.00
18	0.00	0.00
19	0.00	0.00
20	0.00	0.00



Fishery

Fishery

Fishery

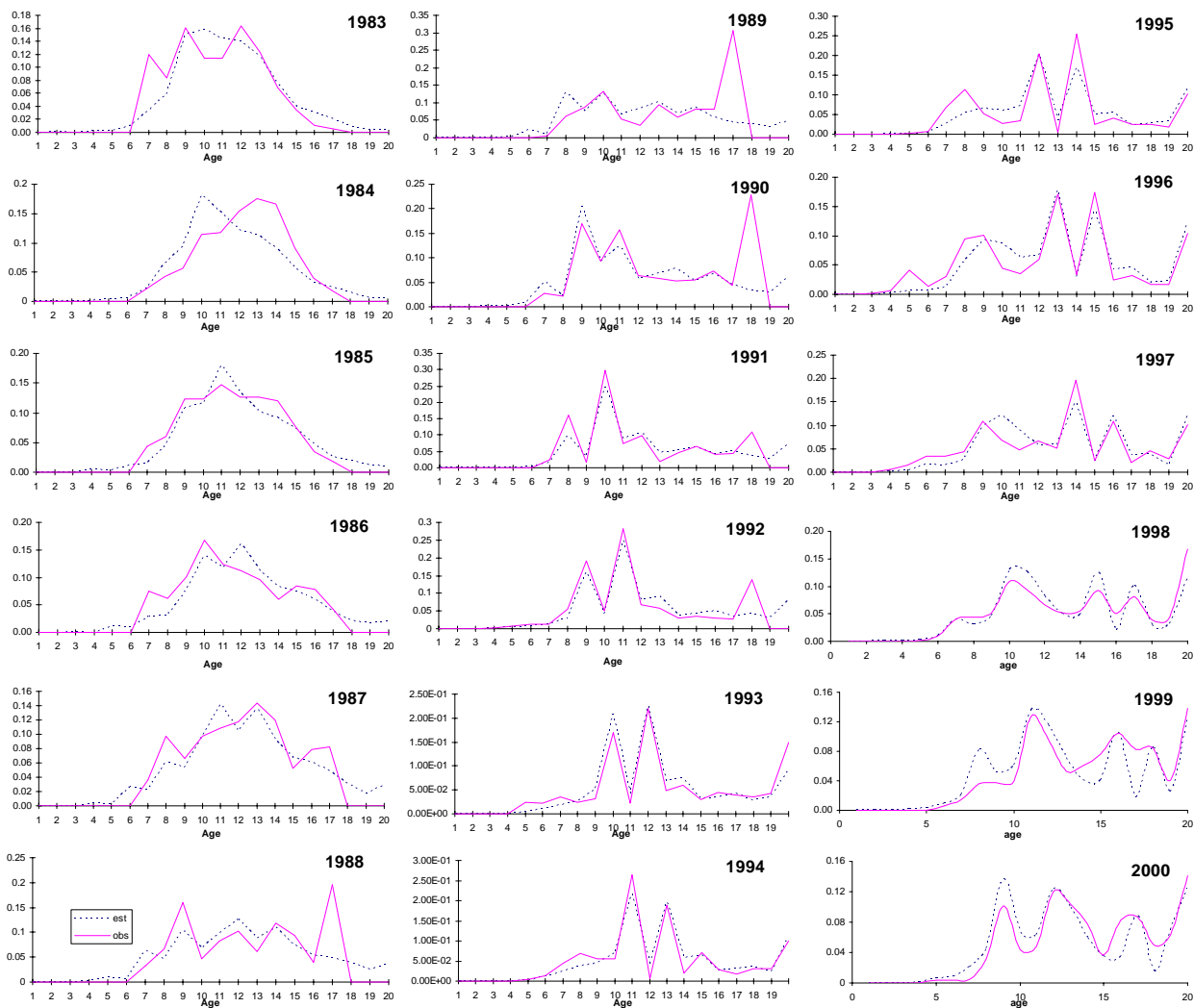
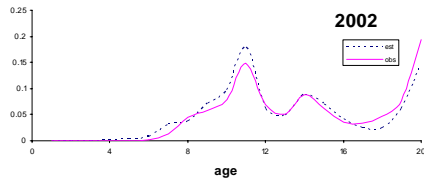


Figure 1 consists of two vertically stacked line graphs. The top graph is labeled '2001' and the bottom graph is labeled '2002'. Both graphs have 'age' on the x-axis (ranging from 0 to 20) and density on the y-axis (ranging from 0 to 0.2). Each graph contains two lines: a dashed line representing the estimated distribution ('est') and a solid magenta line representing the observed distribution ('obs'). In 2001, the 'est' line has a primary peak of approximately 0.18 at age 10 and a secondary peak of approximately 0.11 at age 18. The 'obs' line follows a similar pattern but with lower peaks, reaching about 0.11 at age 10 and 0.09 at age 18. In 2002, the 'est' line has a primary peak of approximately 0.18 at age 10 and a secondary peak of approximately 0.09 at age 18. The 'obs' line follows a similar pattern but with lower peaks, reaching about 0.11 at age 10 and 0.07 at age 18. A legend in the bottom right of the 2002 graph identifies the dashed line as 'est' and the solid magenta line as 'obs'.

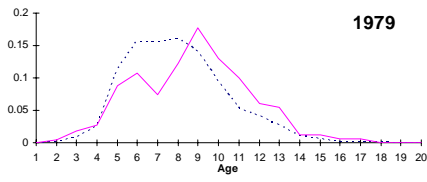


1975

Age	Population (1975)
1	0.00
2	0.00
3	0.00
4	0.01
5	0.05
6	0.25
7	0.18
8	0.28
9	0.15
10	0.05
11	0.02
12	0.01
13	0.00
14	0.00
15	0.00
16	0.00
17	0.00
18	0.00
19	0.00
20	0.00

1979

Age	Population (1979)
1	0.00
2	0.00
3	0.00
4	0.01
5	0.05
6	0.10
7	0.15
8	0.18
9	0.15
10	0.10
11	0.05
12	0.02
13	0.01
14	0.00
15	0.00
16	0.00
17	0.00
18	0.00
19	0.00
20	0.00

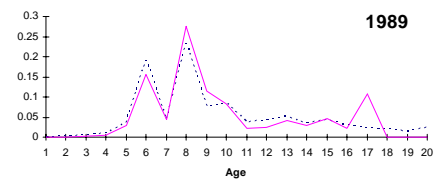
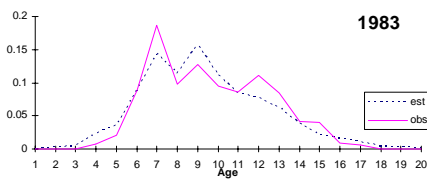
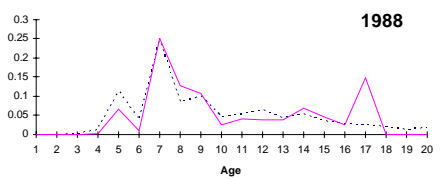
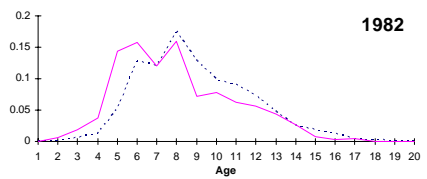
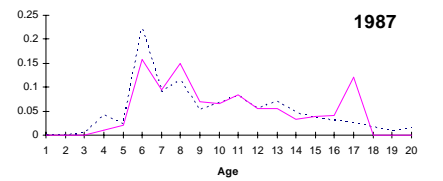
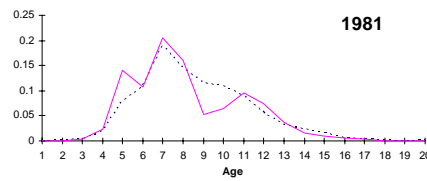
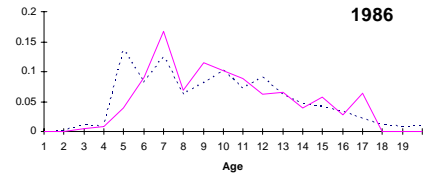
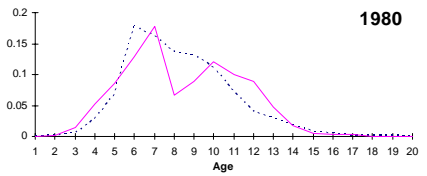
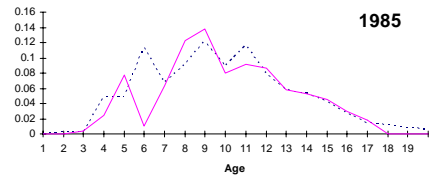


1984

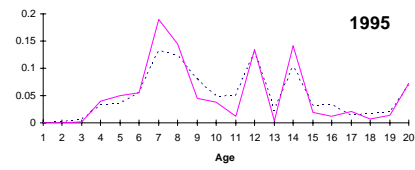
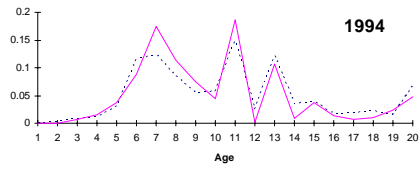
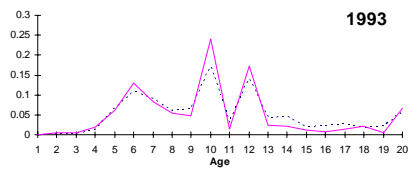
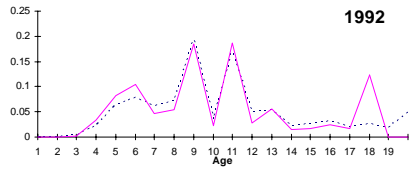
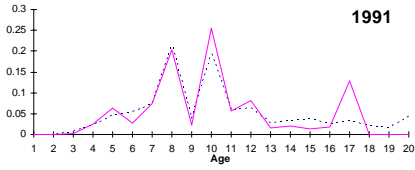
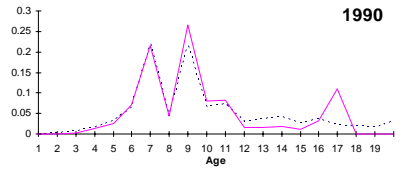
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2	0.00	0.00
3	0.00	0.00
4	0.01	0.01
5	0.02	0.06
6	0.04	0.04
7	0.08	0.08
8	0.10	0.14
9	0.11	0.12
10	0.12	0.13
11	0.11	0.10
12	0.07	0.07
13	0.06	0.06
14	0.05	0.05
15	0.04	0.04
16	0.02	0.02
17	0.01	0.01
18	0.01	0.01
19	0.01	0.01

1985

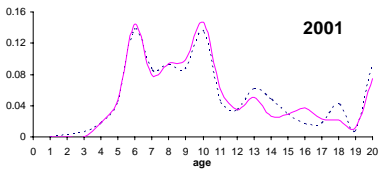
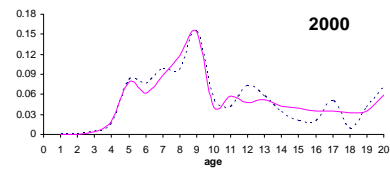
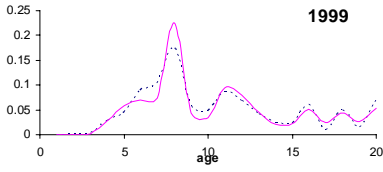
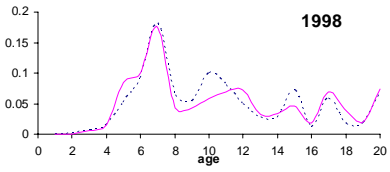
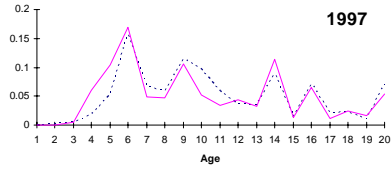
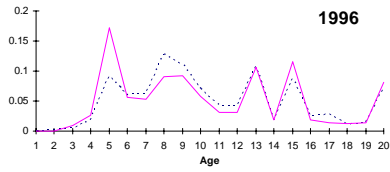
Age	1984 (Solid)	1985 (Dashed)
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2	0.00	0.00
3	0.00	0.00
4	0.01	0.01
5	0.08	0.05
6	0.01	0.11
7	0.06	0.08
8	0.12	0.11
9	0.14	0.10
10	0.08	0.12
11	0.09	0.10
12	0.08	0.08
13	0.06	0.06
14	0.05	0.05
15	0.04	0.04
16	0.02	0.02
17	0.01	0.01
18	0.01	0.01
19	0.01	0.01



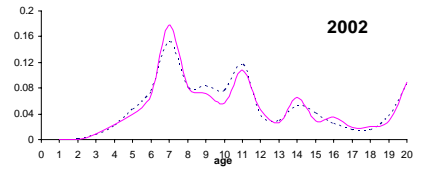
Survey



Survey



Survey



Total catch of yellowfin sole in Alaska Fisheries Science Center surveys in the Bering Sea.

Year	Research Catch (t)
1977	60
1978	71
1979	147
1980	92
1981	74
1982	158
1983	254
1984	218
1985	105
1986	68
1987	92
1988	138
1989	148
1990	129
1991	118
1992	60
1993	95
1994	91
1995	95
1996	72
1997	76
1998	79
1999	61
2000	72
2001	75
2002	76
2003	78

Model estimates of yellowfin sole female spawners (millions) from 1954-2003.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	0.37	1.21	1.74	1.57	1.86	2.29	8.34	18.22	36.69	64.59	99.73	129.07	146.97	156.14	160.13	161.89	162.37	162.13	163.57	163.90
1955	0.18	0.76	2.84	3.39	3.34	2.36	7.85	16.59	33.62	59.28	87.70	113.17	129.02	137.08	140.83	142.17	142.86	142.99	142.35	287.52
1956	0.12	0.36	1.80	5.55	7.22	4.24	8.06	15.59	34.27	54.27	80.37	99.35	112.92	120.10	123.40	124.79	125.22	125.57	125.31	376.71
1957	0.40	0.24	0.85	3.51	11.81	9.15	14.49	16.00	28.69	49.15	73.10	90.34	98.29	104.20	107.17	108.40	108.96	109.10	109.08	436.10
1958	0.30	0.83	0.56	1.67	7.47	14.95	31.28	28.76	29.43	46.10	66.20	82.15	89.35	90.68	92.96	94.12	94.62	94.91	94.76	473.49
1959	0.23	0.61	1.94	1.08	3.55	9.46	51.08	61.99	52.66	46.85	61.24	73.17	79.80	80.91	80.90	80.13	80.64	80.90	80.91	484.40
1960	0.24	0.47	1.44	3.79	2.31	4.48	32.10	99.65	109.45	78.24	56.15	59.74	62.06	62.84	61.61	59.52	59.70	59.96	59.97	419.05
1961	0.14	0.49	1.09	2.81	8.05	2.89	14.97	60.04	159.62	135.05	71.13	39.16	35.22	33.59	32.88	31.74	30.47	30.51	30.54	244.03
1962	0.24	0.29	1.15	2.13	5.95	10.03	9.46	26.46	84.44	153.65	84.86	31.67	14.20	11.54	10.64	10.26	9.84	9.43	9.41	84.71
1963	0.12	0.49	0.67	2.24	4.49	7.34	32.02	15.76	32.42	62.47	65.26	23.48	6.86	2.73	2.15	1.95	1.87	1.79	1.71	17.06
1964	0.11	0.25	1.15	1.31	4.75	5.64	24.60	60.34	25.69	41.37	59.71	48.36	14.79	3.97	1.53	1.19	1.07	1.02	0.98	10.24
1965	0.16	0.23	0.58	2.25	2.79	5.97	18.83	45.87	95.98	31.28	36.87	40.65	27.78	7.79	2.02	0.77	0.59	0.53	0.51	5.56
1966	0.19	0.32	0.55	1.13	4.77	3.52	20.21	36.51	79.84	138.78	36.01	34.25	32.70	20.71	5.62	1.44	0.54	0.42	0.37	4.26
1967	0.31	0.39	0.76	1.06	2.40	6.01	11.86	38.63	61.52	108.54	145.75	29.92	24.41	21.53	13.18	3.52	0.89	0.34	0.26	2.87
1968	0.33	0.63	0.90	1.48	2.26	3.02	20.09	22.18	61.85	75.86	98.57	101.50	17.61	13.19	11.25	6.78	1.80	0.46	0.17	1.59
1969	0.32	0.68	1.48	1.77	3.15	2.85	10.20	38.69	38.03	86.88	83.64	86.88	77.14	12.38	8.97	7.53	4.51	1.19	0.30	1.17
1970	0.45	0.66	1.61	2.89	3.74	3.95	9.48	18.89	60.58	44.94	74.07	53.95	47.07	38.26	5.94	4.23	3.53	2.11	0.56	0.69
1971	0.54	0.91	1.56	3.13	6.14	4.70	13.15	17.59	29.70	72.15	38.76	48.46	29.68	23.72	18.64	2.85	2.02	1.68	1.00	0.59
1972	0.53	1.11	2.15	3.04	6.63	7.65	15.38	23.39	25.08	29.36	47.17	18.11	18.51	10.26	7.93	6.14	0.93	0.66	0.55	0.52
1973	0.47	1.08	2.61	4.19	6.46	8.36	25.80	29.46	39.57	34.36	31.18	39.72	13.10	12.37	6.63	5.05	3.88	0.59	0.41	0.67
1974	0.51	0.96	2.53	5.10	8.89	8.12	27.98	48.55	47.86	50.16	32.52	22.83	24.70	7.49	6.84	3.61	2.73	2.09	0.32	0.58
1975	0.61	1.05	2.25	4.94	10.84	11.23	27.55	54.38	84.99	69.96	58.69	30.80	18.76	18.82	5.52	4.96	2.60	1.96	1.50	0.65
1976	0.39	1.25	2.46	4.39	10.49	13.68	38.02	53.38	94.56	122.64	80.29	54.30	24.68	13.93	13.51	3.90	3.48	1.82	1.37	1.50
1977	0.45	0.80	2.94	4.80	9.34	13.26	46.49	74.40	94.90	142.36	149.92	80.21	47.27	19.96	10.90	10.40	2.98	2.66	1.39	2.19
1978	0.30	0.93	1.87	5.75	10.21	11.81	45.16	91.31	133.47	145.35	178.52	154.49	72.22	39.58	16.16	8.68	8.24	2.36	2.10	2.82
1979	0.20	0.62	2.18	3.66	12.21	12.89	40.01	87.65	159.36	193.94	168.55	167.28	125.48	54.38	28.82	11.58	6.19	5.86	1.67	3.48
1980	0.37	0.41	1.45	4.26	7.78	15.44	43.85	78.46	156.66	242.35	240.65	171.48	148.54	103.58	43.40	22.65	9.05	4.82	4.55	4.01
1981	0.27	0.76	0.97	2.83	9.07	9.84	52.62	86.34	141.57	242.58	308.91	252.95	157.75	127.17	85.75	35.37	18.34	7.31	3.89	6.90
1982	0.73	0.55	1.80	1.89	6.02	11.47	33.56	103.68	156.03	219.87	310.60	326.48	234.08	135.88	105.92	70.31	28.83	14.92	5.93	8.75
1983	0.12	1.50	1.29	3.51	4.01	7.62	39.13	66.22	188.04	243.95	284.33	332.23	306.08	204.36	114.71	88.03	58.07	23.76	12.26	12.06
1984	0.60	0.26	3.52	2.52	7.46	5.08	25.98	77.22	120.08	293.90	315.31	303.94	311.26	267.03	172.40	95.26	72.66	47.84	19.52	19.97
1985	0.19	1.22	0.60	6.87	5.36	9.43	17.29	51.10	138.97	185.02	371.88	328.48	276.91	263.84	218.87	139.11	76.40	58.15	38.17	31.51
1986	0.15	0.39	2.87	1.17	14.61	6.78	32.07	33.85	90.91	209.47	226.56	372.31	286.64	224.51	206.85	168.92	106.70	58.48	44.38	53.18
1987	0.21	0.32	0.91	5.60	2.50	18.47	23.06	62.82	60.32	137.50	257.83	228.24	327.09	234.02	177.25	160.76	130.48	82.26	44.95	74.99
1988	0.29	0.44	0.74	1.78	11.90	3.16	62.84	45.23	112.34	91.83	170.86	262.76	203.04	270.52	187.16	139.54	125.79	101.89	64.04	93.37
1989	0.29	0.59	1.02	1.45	3.78	15.04	10.72	122.72	80.05	167.68	110.83	168.07	224.95	161.41	207.95	141.63	104.95	94.42	76.25	117.80
1990	0.13	0.59	1.38	2.00	3.08	4.78	51.20	21.05	220.04	122.47	209.94	113.98	151.00	187.95	130.41	165.39	111.96	82.80	74.26	152.63
1991	0.14	0.27	1.39	2.69	4.25	3.90	16.30	101.21	38.32	346.67	160.19	227.68	108.47	133.88	161.14	110.07	138.74	93.73	69.11	189.37
1992	0.35	0.28	0.63	2.72	5.73	5.38	13.30	32.20	183.97	60.18	451.18	172.68	215.26	95.53	114.01	135.09	91.71	115.36	77.70	214.28
1993	0.19	0.72	0.66	1.22	5.78	7.24	18.32	26.15	57.89	282.84	75.89	468.14	156.64	181.65	77.95	91.58	107.85	73.07	91.64	231.94
1994	0.18	0.39	1.68	1.28	2.60	7.31	24.70	36.17	47.46	90.61	366.37	81.34	439.86	137.06	153.70	64.93	75.82	89.10	60.19	266.53
1995	0.15	0.37	0.92	3.28	2.73	3.28	24.90	48.60	65.14	73.24	114.91	382.70	74.32	373.96	112.68	124.39	52.22	60.86	71.31	261.48
1996	0.27	0.31	0.87	1.81	6.98	3.45	11.19	49.04	87.76	101.00	93.53	121.06	352.94	63.80	310.40	92.07	101.02	42.33	49.18	268.91
1997	0.15	0.55	0.74	1.69	3.84	8.83	11.75	22.03	88.37	135.53	128.23	97.85	110.79	300.56	52.53	251.62	74.18	81.22	33.93	254.99
1998	0.15	0.30	1.30	1.44	3.60	4.85	30.01	23.00	39.19	133.18	165.93	128.34	85.36	89.80	235.56	40.53	192.94	56.77	61.97	220.44
1999	0.20	0.31	0.71	2.53	3.07	4.56	16.55	59.13	41.55	60.83	170.39	175.19	118.64	74.71	73.44	192.94	32.99	156.75	45.98	228.74
2000	0.23	0.41	0.72	1.38	3.88	15.55	32.71	107.63	65.43	79.48	184.56	166.50	105.04	105.04	62.88	62.97	161.62	27.58	130.65	228.98
2001	0.22	0.48	0.96	1.41	2.94	6.81	13.24	30.68	59.28	168.10	84.47	84.85	172.67	145.04	88.49	52.14	51.90	132.94	22.62	294.91
2002	0.25	0.45	1.13	1.87	3.00	3.72	23.25	25.58	93.45	220.07	91.71	80.85	153.28	124.51	134.58	74.78	43.79	43.50	111.09	265.36
2003	0.25	0.51	1.06	2.21	3.99	3.79	12.68	46.17	47.55	87.67	121.48	236.89	86.57	71.08	120.32	104.21	62.20	36.36	36.00	311.57

Selected parameter estimates and their standard deviation from the stock assessment model.

	Parameter	value	std dev	Parameter	value	std dev
	alpha (q estimation)	0.926	0.087	1970 total biomass	658.50	14.054
	beta (q estimation)	0.178	0.036	1971 total biomass	652.69	14.919
	mean_log_rec	0.661	0.108	1972 total biomass	647.53	15.980
	sel_slope_fsh	1.017	0.024	1973 total biomass	793.78	19.156
	sel_slope_srv	1.517	0.073	1974 total biomass	935.73	22.673
	sel50_fsh	9.054	0.075	1975 total biomass	1142.20	26.754
	sel50_srv	5.254	0.067	1976 total biomass	1345.50	31.043
	F40	0.115	0.001	1977 total biomass	1571.60	35.465
	F35	0.138	0.002	1978 total biomass	1799.70	39.856
	F30	0.167	0.002	1979 total biomass	1933.10	43.772
	Ricker S/R logalpha	-3.239	0.173	1980 total biomass	2089.20	47.603
	Ricker S/R logbeta	-5.404	0.091	1981 total biomass	2232.50	51.091
	Fmsy	0.377	0.050	1982 total biomass	2337.30	54.090
	logFmsy	-0.977	0.133	1983 total biomass	2429.40	56.854
	msy	219.83	26.540	1984 total biomass	2496.20	59.432
	Bmsy	211.58	15.603	1985 total biomass	2504.60	61.813
1954	total biomass	1609.80	136.230	1986 total biomass	2438.10	63.825
1955	total biomass	1651.10	119.040	1987 total biomass	2380.60	65.960
1956	total biomass	1712.30	99.521	1988 total biomass	2335.20	68.116
1957	total biomass	1774.60	79.841	1989 total biomass	2229.60	69.745
1958	total biomass	1843.80	62.179	1990 total biomass	2185.30	71.746
1959	total biomass	1896.70	48.539	1991 total biomass	2203.20	73.863
1960	total biomass	1810.00	39.904	1992 total biomass	2187.30	75.587
1961	total biomass	1453.60	32.040	1993 total biomass	2096.00	76.892
1962	total biomass	1004.00	21.439	1994 total biomass	2052.60	78.492
1963	total biomass	695.11	12.770	1995 total biomass	1964.90	79.858
1964	total biomass	732.31	13.339	1996 total biomass	1894.60	81.408
1965	total biomass	736.37	13.523	1997 total biomass	1817.60	82.978
1966	total biomass	789.96	14.311	1998 total biomass	1690.20	84.346
1967	total biomass	782.88	14.567	1999 total biomass	1643.90	86.323
1968	total biomass	708.40	13.811	2000 total biomass	1628.60	88.365
1969	total biomass	722.81	14.462	2001 total biomass	1599.10	90.896
				2002 total biomass	1586.30	94.109
				2003 total biomass	1571.60	100.140